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   2. Background of Wireless sensor network.
   3. Applications of Wireless Sensor Networks.
   4. Wireless sensor network Components.
   5. Protocols & algorithms of wireless sensor network.
   6. The LEACH Protocol Architecture.
   7. Self-Configuration Cluster Formation.
   8. Determining Cluster-Head Nodes.
   9. Set-up Phase.
   10. Steady-State Phase.
   11. Analysis and Simulation of LEACH.
   12. Simulation Models.
   13. Modeling Set-up and Simulation Results.
   14. Multi-hop LEACH Protocol Architecture.
   15. Self-Configuration Cluster Formation.
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# CONTENTS

ABSTRACT

One of the main challenges which obstacle the large-scale deployment of Wireless Sensor Networks (WSNs) is providing the applications with the required quality of service (QoS) given the sensor nodes' limited energy supplies.WSNs area important tool in supporting applications ranging from environmental and industrial monitoring, to battlefield surveillance and trac control, among others. Most of these applications require sensors to function for long periods of time without human intervention and without battery replacement.Therefore, energy conservation is one of the main goals for protocols for WSNs.

Many routing protocols have been designed based on clustering, Inour thesis will work on implement and anlysis two types of LEACH protocol, and make full comparsion between them in, their function, usage, application, make good expansion of network lifetime for them, features, and their network performance.

The first one is LEACH (**Low Energy Adaptive Clustering Hierarchy**)is an energy-efficient communication protocol, which employs a hierarchical clustering protocol.where cluster heads are randomly rotated to balance energy of network. The principle of LEACH is how to determine cluster and cluster head. The cluster head accepts data from other sensors within the same cluster, aggregate data and finally sends data to the Base Station (BS),So this role is rotated among all the nodes in the networkto balance the the network energy consumption among nodes.

The second one is Multi-HopLEACH which use in large zone and support using this protocol in military applications where sink is at the edge of the monitored area or farther.

## 1 Introduction

Wireless sensor network become a very popular with a huge research these day due to the usage of these network in different life fields and applications, the tremendous technological advances always prompted the researchers to provide what is new to cover consumer demand and the lowest prices, low power, multi–funcational wireless sensor nodes which is powered by batteries, its small in size, but capable of sensing, mointoring and reacting to specific physical or enviromental conditions civil or military sensor networks include large-scale acoustic ocean surveillance systems, such as temperature, pressure, speed, sound, humidity, tracking target, smart home, intelligent buildings, predictive maintenance, energy saving, smart grid, health care systems,, hazardous materials, fire, vehicular speed mointoring, traffic rating system, building internal surveilance, detection of submarines, and so on, Due to recent technological advances, the manufacturing of sensors has become technically and economically feasible .

advances in semicoductor and communication technology and the deveploment of system on a chip (SoC) technogly have led to new research and Manufacturing low cost sensors with higher storage and computaionalcapabilties this is one of the advantages and benefits of wireless senosor networks, but the enegryresouce limitation still a major problem, Although WSNs have get a lot of develpoment, but WSN is based on IEEE 802.15.4 standard, set for low rate- wireless personal networks (LR-WPANs) which is completely different from Internet. The first problem in developing WSNs is how to publish data of WSNs over Internet[1]

### 1.1 Wireless Sensor Network

A Wireless sensor network (WSN) or sometimes called a wireless sensor and actor network (WSAN) is a net of small sensor nodes, connected by using wireless communication technology to collect data sensor network consists of various detection stations called sensor nodes, each one of them is small, lightweight and portable; WSN has a wide range of applications, Sensors market is extremely diverse and sensors are used in many industries sensors manufacturers are look forword to find new ways to build on new technolgy with lower cost, simply use which meet the contious demand for sophisticated applications.

### 1.2 Background of Wireless sensor network.

The origin of the research of WSNs can be traced back to the distributed sensor networks(DSN) program in the Defense Advanced Research Projects Agency (DARPA) in 1980. At that time, the ARPANET (Advanced Research Projects Agency Network) had been operantioal for several years, a round 200 announcers at universities and research institutes.

DNSs were assumed to have many spatially distributed low-cost sensing nodes collaborated with each other but operated independently, The information being routed to whichever node whose the best able to use the information. At that time, this was actually an ambitious program. There were no personal computers and workstations; processing was mainly performed on minicomputers and the Ethernet was just becoming popular. Technology components for a DSN were identified in Distributed Sensor Nets workshop in 1978 (Proceedings of the Distributed Sensor Nets Workshop,1978). These included sensors (acoustic), communication and processing modules, and distributed software. Distributed acoustic tracking was chosen as the target problem for demonstration. Researchers at Carnegie Mellon University (CMU) developed a communication-oriented operating system called Accent (Rashid & Robertson, 1981), which allowed flexible, transparent accesss to distributed resources required for a fault-tolerant DSN.

A demonstrative application of DSN was a helicopter tracking system (Myers et al., 1984), using a distributed array of acoustic microphones by means of signal abstractions and matching techniques, developed at the Massachusetts Institute of Technology (MIT). Even though early researchers on sensor networks had in mind the vision of a DSN, the technolgy was not quite ready. More specifically, the sensors were rather large ( i.e shoe box and up ) which limited the number of potential applications. Further, the earliest DSNs were not tightly associated with wireless connectivity. Recent advances in computing, communication and microelectromechanical technology have caused a significant shift in WSN research and brought it closer to achieving the original vision. The new wave of research in WSNs started in around 1998 and has been attracting more and more attention and international involvement. In the new wave of sensor network research, networking techniques and networked information processing suitable for highly dynamic ad hoc environments and resource constrained sensor nodes have been the focus. Further, the sensor nodes have been much smaller in size (i.e. pack of cards to dust particle) and much cheaper in price, and thus many new civilian applications of sensor networks such as environment monitoring, vehicular sensor network and body sensor network have emerged. Again, DARPA acted as a pioneer in the new wave of sensor network research by launching an initiative research program called SensIT (Kumar & Shepherd, 2001) which provided the present sensor networks with new capabilities such as ad hoc networking, dynamic querying and tasking, reprogramming and multitasking. At the same time, the IEEE noticed the low expense and high capabilities that sensor networks offer. The organization has defined the IEEE 802.15.4 standard (IEEE 802.15 WPAN Task Group 4, n.d.) for low data rate wireless personal area networks. Based on IEEE 802.15.4, ZigBee Alliance (ZigBee Alliance, n.d.) has published the ZigBee standard which specifies a suite of high level communication protocols which can be used by WSNs.

Currently, WSN has been viewed as one of the most important technologies for the 21st century (21 Ideas for the 21st Century, 1999). Countries such as China have involved WSNs in their national strategic research programmes (Ni, 2008). The commercialization of WSNs are also being accelerated by new formed companies like Crossbow Technology (Crossbow Technology, n.d.) and Dust Networks (Dust Networks, Inc., n.d.)[2]

1.3 Applications of Wireless Sensor Networks

The autonomous nature of the wireless sensor networks makes this unique technology flexiable and adaptable with respect to a wide array of applications, below some of the major applications for WSNs.

1. Military Applications: Always the military missions involved with high risk to the human personnel. Thus, unmanned surveillance missions using wireless sensor networks have a very wid applications in the field of military purposes for example surveillance, monitoring inimical forces,monitoring friendly forces and equipments,military- theater or battlefield surveillance, targeting ,battle damage assement, nuclear, biological, and checmical attack detection. Wireless ad hoc networ technology has been used for militray purposes for a long time, but the deployment of wireless sensor network is easier (by throwing them from an aircraft, for example), to gather different data from a battlefield, and to collect data about the enemy (for example, to track the enemy through some region).

WSNs development for military purposes should be energy – efficient, fault tolerant, disposable and support network dynamics. Destruction of a few nodes by enemy forces should not hamper the operation of such networks. Defense Advanced Research Projects Agency (DARPA) organized the Senso Information Technology (SensIT) explored two important aspects of military WSNs – dynamic networking of sensors and information processing and extraction from such networks [3].

2. Habitat Monitoring: Mointoring plants and animals habitats on a long- term justification is widely employed by researchers in Life Sciences. Anyhow, human presence in such monitoring usually causes annoyances in animals and plant conditions, and that will increase stress and reduce breeding successes increasing predation, So the Sensor networks present a great development for monitoring by overcome many difficulties associated with old methods of monitoring.
botanical studies for example Sensors can be deployed on small islets where it would be unsafe or difficult to make survey studying frequently more economical method for conducting long-term studies than traditional personnel-rich methods.

The College of the Atlantic (COA) is field testing in-situ sensor networks for habitat monitoring. COA has ongo- ing field research programs on several remote islands with well established on-site infrastructure and logistical support. Great Duck Island (GDI) (44.09N,68.15W) is a 237 acre is- land located 15 km south of Mount Desert Island, Maine. The Nature Conservancy, the State of Maine and the College of the Atlantic hold much of the island in joint tenancy. [4] Wireless sensors were used to measure temperature, pressure, humidity and other conditions of the birds' burrows. Another system called ZebraNet was used to track zebra and other animals in Kenya[5].

3. Environment Monitoring:Wireless Sensor networks can be used in a wide range of environmental monitoring applications such as forest fire detection, flood detection, air pollution monitoring, greenhouse shows accurate measurement of temperature with high spatial resolution, horizontal as well as vertical, is recommended in order to achieve reliable and consistent results , gas monitoring ,WSNs to monitor dangerous gases such as CO, NO2, and CH4 have already been deployed in some cities (London and Brisbane) [6, 7, 8].

4. Agriculture Monitoring: Wireless sensors may be deployed over large areas of crop fields and can monitor different parameters such as moisture, temperature, humidity , fertilizer content of soil, PH level and pesticide levels ,and according that can automate the processes of irrigation application of fertilizer and pesticides, for precision agriculture these parameters are very necessary and that minimizing human intervention and increase the yield [9][10]

5. Industrial Monitoring: There are three types of WSNs mointoring in the industrial field process monitoring, staff monitoring, and machineries monitoring and controlling companies often use manual labor- internsive techniques and that make the cost high with human error, but some of mointoring processing can not be done by human beings either they are out of reach where wired infrastructure for such maintenance is costly due to the cost of wiring and inaccessible locations, such as rotating machinery and it is dangerous to monitor them directly ( for example because of RF interference/Highly caustic or corrosive environments/High humidity levels /Vibrations /Dirt and dust)using WSNs are benefical in such cases. WSNs use in building access controls, HVAC ((heating, ventilating and air conditioning)controls, lighting controllers, Thermostat, Lifts/Elevators/ Escalators, Remote alarm triggering, water management, Electrical blinds[11, 12].

6. Health Monitoring:Wireless personal health monitoring or body networks WSNs change the way we monitor health conditions by providing a non-invasive, inexpensive, continuous and ambulatory health monitoring. In some modren hospital sensor networks are constructed to mointor patient physiological data, control brain and heart of the patients inside a hospital ,where the patients wear small body sensors that monitor the patient's bio-signals ,and the collected data are transmitted over a hand held device. Alarms and bio-signals may be transmitted over the Internet to a health professional for real-time diagnosis [13].

## 1.4 Wireless Sensor Network Components

The WSN construct from several parts, node or sensor nodes, where they are connected with each other wirelessly by their radio transceivers which have an internal or external antenna. In addition to microcontroller is part of WSN which used for interfacing with sensors and an energy sources.

The deployement of WSNs depends on how many nodes requires, which depend on the size of the area need to be monitored and the frequency of the sampling required, and the quanitiy of nodes. To simplify the communication in sensor networks an important machanism used it's called clustering in large multi-hop wireless sensor networks to make the power consumption less; Each cluster is managed by a node which called Cluster Head (CH), The rest nodes called cluster nodes, Each cluster head is phyiscally located within its cluster, and reponsible for selecting some of its sensing neighbors to cover it, in designing cluster head there is no strict ordering that determines the order in which cluster- heads select their active sensors, However, neighboring cluster - heads need to Cooperate between themselves through message exchanges to select a minimum number of sensors to cover their clusters [14] as shown in figure 1.1.

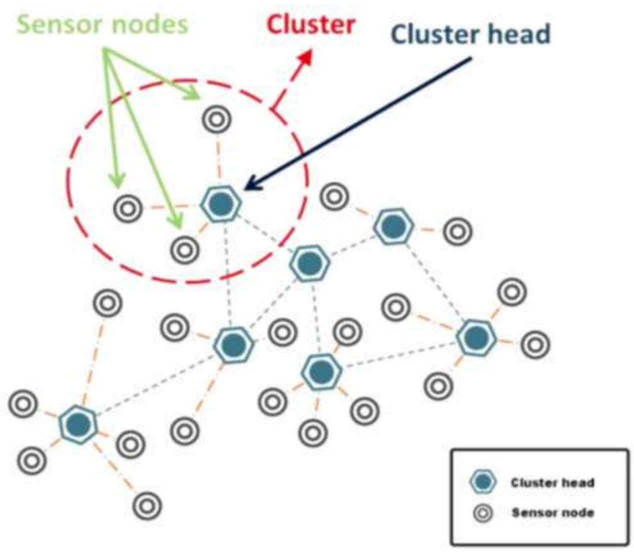


Figure 1.1 – Clustering of wireless sensor network

## 1.5 The purpose of clustering

The purpose of clustering:

- simplify the communications in the sensor networ;
- transmit aggregated data to the data sink;

- reducing number of nodes taking part in tranmission;
- scalability for large number of nodes;
- reduce communication overhead;
- ecient use of resources in WSNs.

Wireless sensor network consists of three main components, nodes, gateway, and software. The sensor nodes' transmission, over the physical medium, can be based on radio frequency (RF), infrared or optical communication, Most of the WSNs are based on RF communication.

In RF communication based WSNs the sensor nodes are kit up with below mentioned components:

- The transducer: The transducer generates electrical signals basis on sensed physical effects and phonomena.
- The processing unit is the intelligence of the sensor node, It performs calculations and controls the other components of the node.
- The microcomputer processes and stores the sensor output.
- The transceiver receives commands from a central comupter and send out data to that computer.
- power source: it is typically an AA sized battery (or two of them ), but smaller batteries or energy scavenging can also be used depending on the node characteristic.
- Memory: Sensor node memories include in-chip flash memory and RAM of a microcontroller and external flash memory – off- chip RAM is rarely used. While Flash memories are used due to its cost and storage capacity.
- Global Posittioning System (GPS): Geo – Positioning System, The sensor node also often has location and positioning knowledge that is acquired through a global positioning system (GPS) or local positioning algorithm, the disadvantage of GPS systems is that add extra cost to the system in addition to energy consumption costs and accuracy GPS[15].

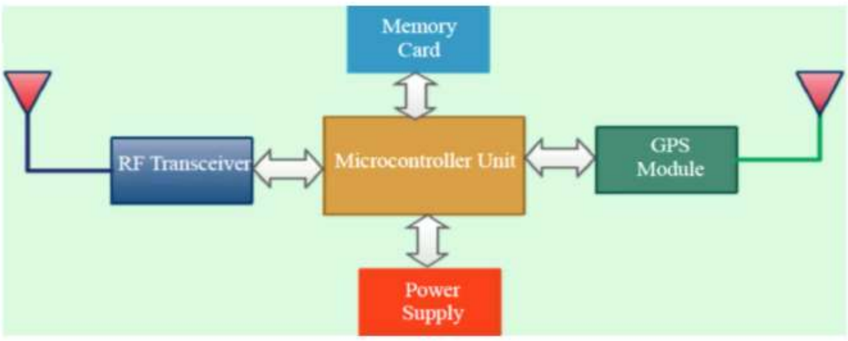


Figure 1.2 – Wireless sensor node components

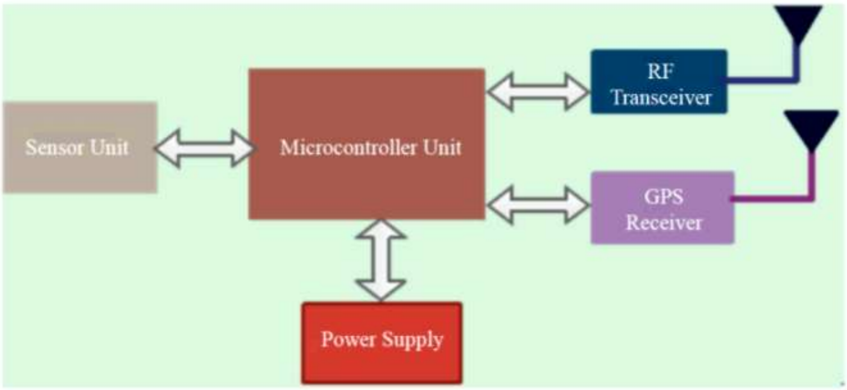


Figure 1.3 – Proposed WSN gateway node architecture

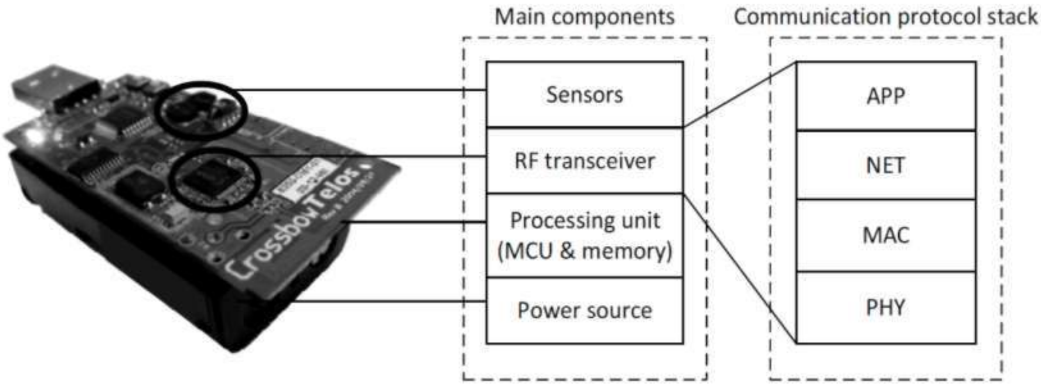


Figure 1.4 – Sensor node (TelosB [8]) main components
and communication protocol stack layers

The deployment of a WSN has many keys needto take in consideration, the most significant and the first one is how many nodes required in the deployement, and the quantity of nodes required will primarily be regulated by the size of the area to be monitored and the frequency of the sampling required. The Second factor is the node sampling frequency value which depend on what aspect of the environment is being monitored[16].

1.6 Protocols & algorithms of wireless sensor network.

In WSN, the main task of a sensor node is to sense data and sends it to the base station in multi hop environment for which routing path is essential. For computing the routing path from the source node to the base station there is huge numbers of proposed routing protocols exist[17].

The design of routing protocols for WSNs must take in consideration the following requirments:

– The power and resource limitation of the network nodes;
– The time-varying quality of the wireless channel;

- The possibility for packet loss and delay.

To address these requirements in the design, several routing strategies for WSN have been proposed

Routing Protocols can be classified :

- Based on Mode of functioning and type of target applications into Proactive, Reactive and Hybrid:
  1) In a Proactive Protocol the nodes switch on their sensors and transmitters, sense the environment and transmit the data to a BS through the predefined route. The Low Energy Adaptive Clustering hierarchy protocol (LEACH) utilizes this type of protocol.
  2) In Reactive Protocol if there are sudden changes in the sensed attribute beyond some pre-determined threshold value, the nodes immediately react. This type of protocol is used in time critical applications The Threshold sensitive Energy Efficient sensor Network(TEEN) is an example of a reactive protocol.
  3) Hybrid Protocols Incorporate both Proactive and Reactive concepts. They first compute all routes and then improve the routes at the time of routing, Adaptive Periodic TEEN (APTEEN) is an example of Hybrid Protocols.
- Based on Participation style of the nodes into as Direct Communication, Flat and Clustering Protocols:
  1) In Direct Communication Protocols, any node transmit its information to the BS directly. For exampleSPIN protocol.
  2) In the case of Flat Protocols, node transmit the data to the sink, but first need to find a valid route to BS, and then send. Rumor Routing is an example of this type of protocol.
  3) Clustering protocols, where the total area is divided into numbers of clusters. Each one of these clusters has a cluster head (CH) and the cluster head directly communicates with the BS, The Threshold sensitive Energy Efficient sensor Network(TEEN) is an example of a clustering protocol.
- Depending on the Network Structure as Hierarchical, Data Centric and Location based:
  1) Data centric protocols are query based and they depend on the naming of the desired data, thus it eliminates much redundant transmissions. The BS sends queries to a certain area for information and waits for reply from the nodes of that particular region. SPIN was the first data centric protocol.
  2) Hierarchical routing is used to perform energy efficient routing. Higher energy nodes can be used to process and send the information and low energy nodes are used to perform the

sensing in the area of interest examples: LEACH, TEEN, APTEEN.

3) Location based routing protocols need some location information of the sensor nodes. Location information can be obtained from GPS signals, received radio signal strength, etc.GEAR is an example of a location based routing protocol.[18]

## 2 The LEACH Protocol Architecture

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a TDMA-based MAC protocol which is intergarted with clustering and a simple routing protocol in wirless sensor networks(WSNs). The goal from this LEACH is to reduce the energy consumption required to create and maintain clusters in order to improve the life time of the wireless sensor network and that more econamically use[19].

LEACH is one of the most popular clustering algorithms used in WSNs is an adaptive, self organizing and clustering protocols. It introduces the concepts of rounds. LEACH assumes that the BS is fixed location, all sensor nodes are homogenous and have limited energy source, sensors can sense the environment at a fixed rate and can communicate among each other.

LEACH( Low-Energy Adaptive Clustering Hierarchy) will design and implement by using Matlabsoftware from MathWorks company, a protocol architecture for wireless sensor network that achieves low 14hresh dissipation without sacrificing applications-specific quality. Since data are correlated and send to the base station, require a high level description of the events in the environment which the nodes are sensing, the nodes can collaborate locally to reduce the data which need to be transmitted to the base station. The nodes which close to each other have the strongest correlation, suggesting the use of a clustering infrastructure that allows nodes that are close to share data. Therefore, LEACH uses a clustering architecture, where the nodes in the cluster send their data to a local cluster-head. This node is responsible for receiving all the data from nodes within the cluster and aggregating this data into a smaller set data which carry the information that show the events which sensed by those nodes. Thus the cluster-head takes a number of these data signals and reduce it (total number of bits ) while mainting the effective data. The cluster-head should take on this rule and send this data to the base station, but that make the enegery consumption of cluster-head higher then the rest nodes in the cluster and quickly die.

LEACH may have rotation for the role of cluster head among all nodes in the network to distribute moderately the enegy load. Once clusters have been formed, the nodes must communicate their data to the cluster-head node in an energy-efficient manner. In wireless sensor network this is accomplish using different types of multiple access protocols, In LEACH using a time-division multiple access(TDMA) protocol because it has two adavantage shown below:-

- firstly make the nodes entire the sleep state when they are not transmitting data to the cluster head and shut down some internal compenents;
- secondly one is to prevent the collisions of data within cluster, so that save time and energy.

For sensor network, we make the following assumptions:

- the base station(BS) is located in the centre of the area which its 15hreshold15a which the nodes are sensing;
- all nodes in the network are homogenous and have limited energy;
- all nodes have the same opportunity to be a cluster head during rounds;
- the node which take in it's responsibility of being a cluster head perform data 15hreshold15a and send this data to the base station. We propose a modification to LEACH's cluster head selection process to reduce energy comsuption. And this prolong network lifetime more.[20]

Figure below shows a simple represnation of LEACH protocol

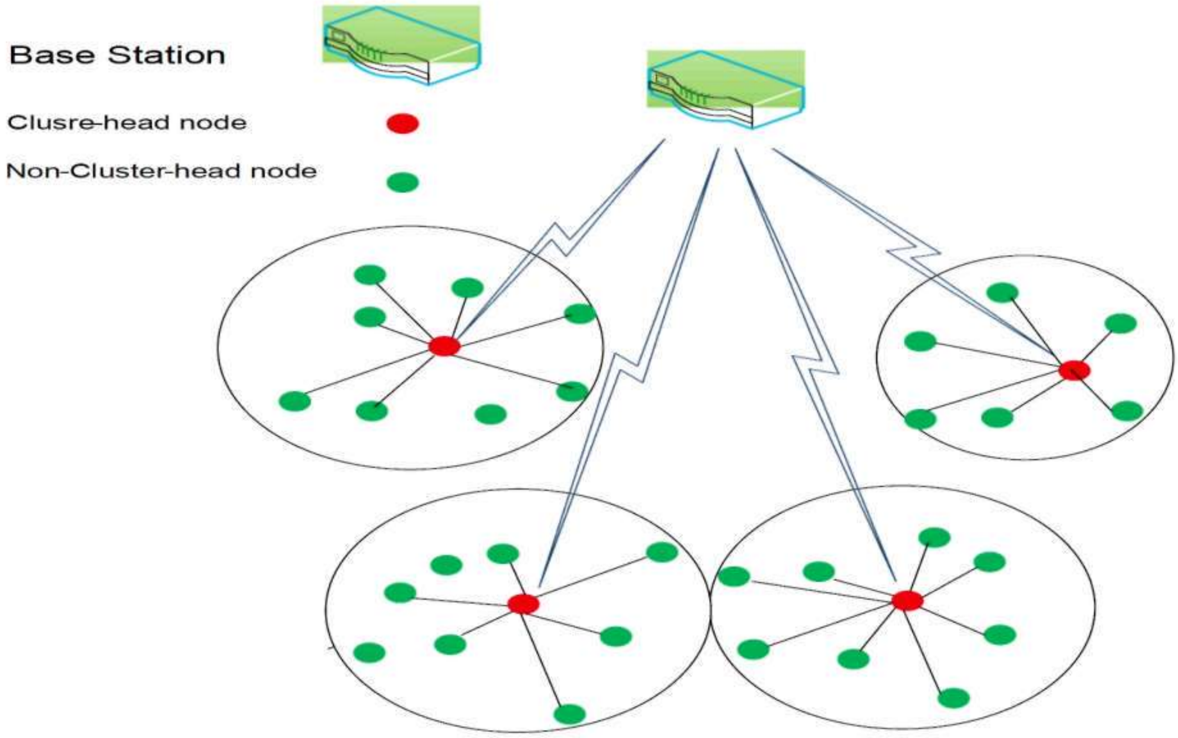


Figure 2.1 – LEACH protocol

The remote 15hreshold15 of an environment is the most typical application that microsensor networks support. Since individual modes' data are correlated in a microsensor network, the end-user does not require all the (redundant) data; rather, the end-user needs a high-level function of the data that give a full description about the events 15hreshold in the environment. We chose a clustering infrastructure as the basis for LEACH. This allows the whole data from nodes within the cluster to be processed locally, and that will reduce the data set that needs to be transmitted to the end-user. Aggregating a large amount of data into a smaller set of data and then send them to the base station that will save more energy and it would be economically to a certain extent.

In LEACH, the nodes organize themselves into local clusters, one of these node will take the role of being a cluster-head and the rest nodes must transmit their data to the cluster-head, perform signal processing functions on the data, by single hope transmission the data transmit the base station, But being a cluster-head node is much more energy-intensive than being non-cluster-head node, and all the node have the same limited enegery, Therefore LEACH incorporates randomized rotation after fixed intervals, In this way, the energy load of being a cluster-head is evenly distributed among all nodes. When cluster-head node dies by using all its energy, all the nodes that correlating to this local cluster lose communication ability.

Macintosh convention taking into account TDMA(Time Division Multipile Access) is incorporated in LEACH with grouping and a basic steering convention for two reasons:

- firstly using TDMA in Media access in LEACH make the energy disspation in the non-cluster head nodes less by creating a TDMA schedule that tells the node exactly when to transmit its data. This make the nodes have sleeping state with internal modules powered-down, as long as possible;
- secondly using a TDMA schedule for data transfer prevents intra-cluster collisions.

The operation of LEACH is divided into rounds, where each round has two phases as mentioned below:

- first Phase a set-up phase that begin when the clusters are organize;
- second Phase a steady-state phase where seveal frames of data are 16hreshold16a from the nodes to the cluster-head then base station, The steady-state phase is longer than the set-up one to minimize the set-up overhead as showin in figure 2.2 below.

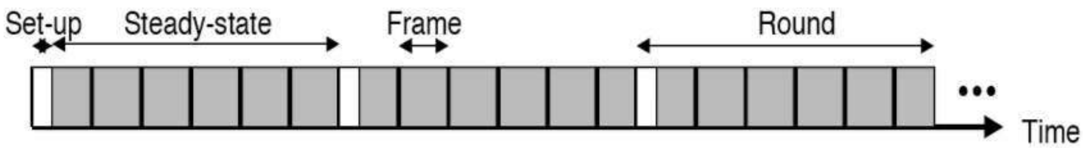


Figure 2.2 – Timeline showing LEACH operation Adaptive clusters are formed during the setup phase and data transfers occur during the steadystate phase

### 2.1 Self-Configuration Cluster Formation

LEACH forms clusters by using an algorithm, where the nodes make a decisions without any centralized control. This feature has many advantages we could summarize as mentioned below:

- limited the connection with the base station and that very necessary to reduce the power consumption in general for whole the sensor network;
- the distributed formation of cluster could be exhausted without having the precise location of any of the node in the network and that reduce the 17hresh consumption per bit through transmission;
- setting up the clusters there is no necessity for global communications, where the decision of forming a good cluster is completely belong to local decision made independently by each node.

### 2.2 Determining Cluster-Head Nodes

We mentioned that the wireless sensor network have many nodes, and we would like to make the consumption of energy among all the nodes in the network evenly distributed to maximum the time until the first node death, So we want to design the algorithm such that there are a certain number of clusters, K, during each round. As being cluster-head node there are many tasks such like perform signal processing functions on the data, aggregating and transmit data to base station. Therefore, the cluster formation algorithm should be designed such that nodes start with the same amount of energy.

In LEACH, at the 17hreshold of round r+1 (that start at time t) the probability of being cluster-head for nodes, Pi(t). according to below formula the expected number of cluster-head nodes for this round is K, Thus:

$$E[\#\ \mathrm{CH}] = \sum_{i=1}^{N} P_i(t) * 1 = k \quad (2.1)$$

Where N is the total number of nodes in the network. All the nodes are cluster-heads the same number of times requires each node to be a cluster-head once in N/K rounds. Equation (2.2) shows the probability for each node i to be a cluster-head at time t:

$$P_i(t) = \begin{cases} \frac{k}{N - k*(r \bmod \frac{N}{k})} & : \ C_i(t) = 1 \\ 0 & : \ C_i(t) = 0 \end{cases}, \quad (2.2)$$

where r: represent the number of rounds that have passed.

Ci(t)= 0 if the node i is cluster-head mathematically expressed in the denominator with the part (r mod N/K ) rounds which has been already a cluster-head recently and its equal 1 otherwise.

Therefore, only nodes that have been already clusters recently, and which presumably have more energy available than nodes have recently performed this energy-intensive function, may become cluster-head at round r+1. While the whole part ( N – K*r) of the denominator shows the expected numbers of nodes that have not been cluster-heads in the first r rounds, So expect all the nodes have been cluster-head once after N/K rounds.

Since Ci(t) is 1 if node i is eligible to be a cluster-head at time t and 0 otherwise, We could represented mathematically as per equation mentioned below

$$E[\sum_{i=1}^{N} C_i(t)] = N - k * (r \bmod \frac{N}{k}) \tag{2.3}$$

The summation term represents the total number of nodes that are eligible to be a cluster-head at time t.From above equation we can conclude that the energy at each node is approximately equal after every N/K rounds. According to equations (2.3 and 3.3), we can reformulated the equation of total number of nodes as shown below:

$$\begin{aligned} E[\# \text{ CH}] &= \sum_{i=1}^{N} P_i(t) * 1 \\ &= (N - k * (r \bmod \frac{N}{k})) * \frac{k}{N - k * (r \bmod \frac{N}{k})} \\ &= k \end{aligned} \tag{2.4}$$

From equation (2.4) k can be determined analytically based on the energy dissipation models for computation and communication and the network topology. Assumption that all nodes start with an equal amount of energy.

2.3.1 Set-up Phase

When the nodes elected themselves to be cluster-heads using Equation (2.2) which shows the probability of nodes to be a cluster head, the cluster-head nodes must let all other nodes in the network know that they have chosen this role for the current round. To achieve that, each cluster-head node broadcasts an advertisement message(ADV) using CSMA MAC protocol[21].

Carrier Sense Multiple Access (CSMA) is a probabilistic Media Access Control (MAC) protocol in which a node verifies the absence of other traffic before transmitting on a shared transmission medium, such as an electrical bus, or a band of the electromagnetic spectrum.

Carrier sense means that a transmitter attempts to determine whether another transmission is in progress before initiating a transmission. That is, it tries to detect the presence of a carrier signal from another node before attempting to transmit. If a carrier is sensed, the node waits for the transmission in progress to end before initiating its own transmission. In other words, CSMA is based on the principle “sense before transmit” or “listen before talk”.[22]

The advertisement message (ADV) we could define as a small message containing the followings:

- the node’s ID;
- a header that define and make this message as an announcement message;

The message must be broadcast to reach all other nodes in the network for couple reasons:

- first to make sure that all nodes know the advertisement to avoid collisions when CSMA is used;
- since there is no guarantee that the nodes that select themselves to be cluster-heads are evenly distributed throughout the network, using enough power to reach all nodes ensures that every node can become part of a cluster. Because if the power of the advertisements messages cannot reach the node which located at the edge of the network and therefore may not be able to participate in this round of the protocol. Therefore, the transmit power is set up to enough high-level to make sure that all nodes of the network can get advertisement message.

Each non cluster-head node determines to which it belongs by choosing the cluster-head which requires the minimum communication energy, depend on the received signal strength of the advertisement from each cluster-head. Assuming that the propagation channels for pure signal strength are symmetric, The communication between cluster-head and nodes depend on closest distance between sensor and cluster-head, where the cluster-head advertisement heard with the largest signal strength is the cluster-head to whom the minimum amount of transmitted energy needed for communication.

The nodes transmit a joint-request message (Joint-REQ) to the chosen cluster-head after confirm the cluster-head which it belongs to. To prolong the network time life the node has an idea about the minimum required level of the power which need to reach the cluster-head, so it’s power is adjustable, other nodes cannot sense this transmission signal and may they send their own ones as well [23].

The cluster-heads is LEACH protocol work look like a local control centers to coordinates the data transmissions in their cluster. They set up a TDMA (Time Division Multiple Access) schedule ans send it to the nodes to prevent the collisions among data messages in addition to allows the radio components of each non cluster-head o be turned off (sleepy mood) at all the times except during their transmission time, to make the energy consumption as less as possible. The set-up phase complete and finish after all the nodes know the TDMA schedule, and the next phase begin to transmit the data and this phase called steady-state phase.

We could make and show a flow-graph of the distributed cluster formation algorithm of LEACH protocol.

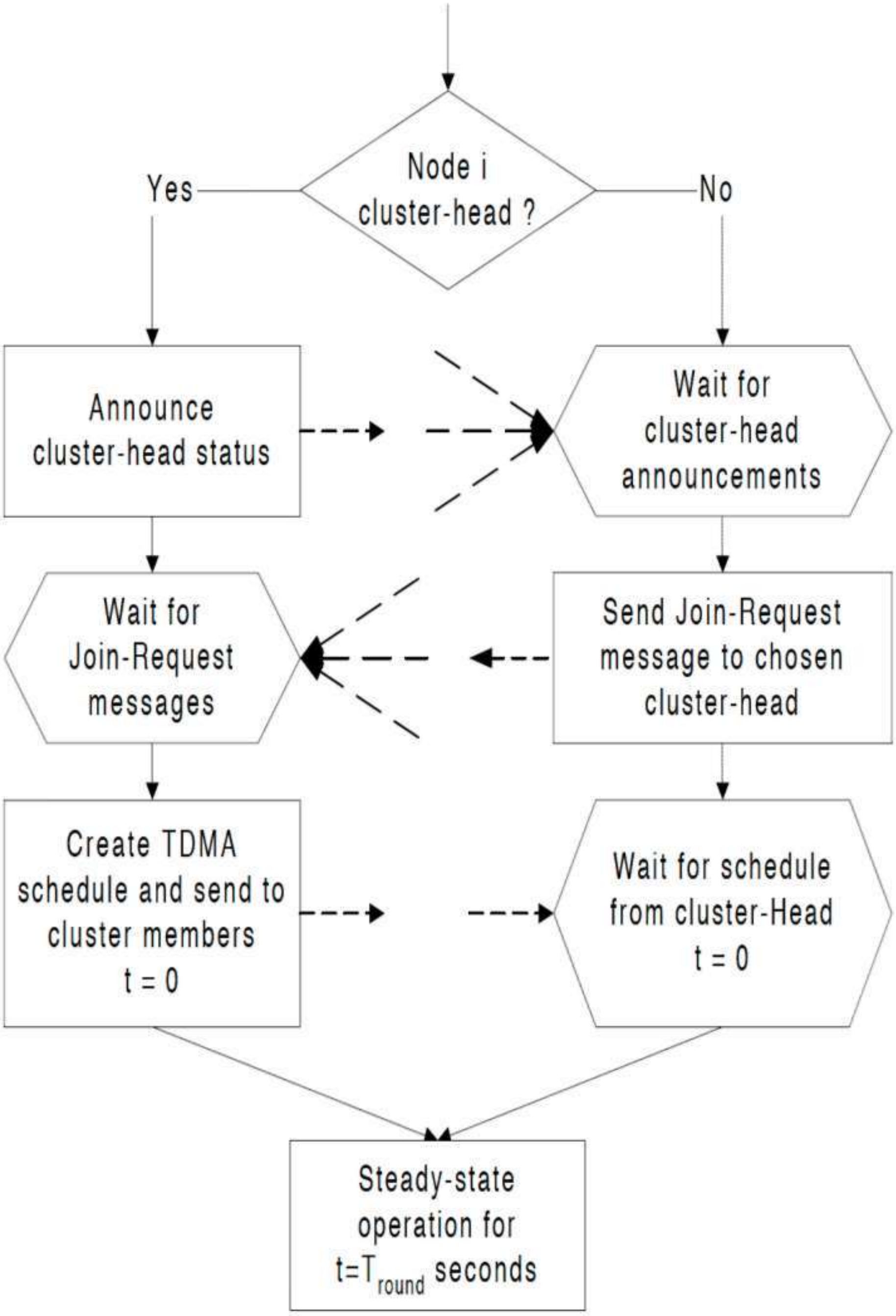


Figure 2.3 – Flow graph of the distributed cluster formation algorithm for LEACH

### 2.3.2 Steady-State Phase

The steady-state operation is divided into frames (see figure 2.2), where each node send it's own data to the cluster-head one time per frame during it's allocated transmission slot. The node transmits data in each slot is constant, Therefore the time for a frame of data transfer depends on the number of nodes in the cluster. While the distributed algorithum for determining cluster-head nodes ensures that the expected number of clusters per rounds is k, it does not guarantee that there are k clusters at each round. Aslo, the set-up protocol does not guarantee that nodes are evenly distributed among the cluster-head nodes. And that reason make the numbers of nodes per cluster in LEACH highly available, and the amount of data each node can send to the cluster-head varies depending on the number of nodes in the cluster.[24]

To reduce energy dissipation the following procedure will be take in consideration in the designing :

- each non-cluster-head nodes uses power control to set the amount of transmitted power based on the received strength of the cluster-head advertisement;
- eurn off the radio of non-cluster-head nodes till their allocated transmission time;

By using the TDMA techinqethe nodes send their own data to the cluster-heads with fixed total bandwidth, below the characterstics of this schedule :

- TDMA schedule is efficient use of bandwidth;
- low latency approach;
- being energy-efficient.

The cluster-head should keep its receiver on to receive all the data from other nodes in the cluster and performing the data aggregated, and then resultant data are sent from the cluster-head to the base station. If the distance of transmission from cluster-head to base-station is far, and the transmitted data is large, this is a high-energy transmission. Below figure 2-3 shows a flow-chart of steady state operation.

Figure 2.4 shows the time-line for a single round of LEACH, stating from the time clustering are formed during the set-up phase, through the steady-state operaion when data are transferred from the nodes to the cluster-heads and then forwarded to the base-station.

The Mac and routing protocol were designed to ensure low energy dissipation in the nodes and no collisions of data messages within a cluster, but radio is inherently a broadcast medium such like transmission in one cluster will affect (and almost degade) communication in nearby cluster. Figure 2.4 shows an illustrative simple example for the range of communication for a radio, we see that A's intend transmit for node B, but collides with and corrupt any concurrent transmission intended for node C.

In LEACH to reduce inter-cluster interference, each cluster in LEACH communicates using direct-sequence spread spectrum(DS-SS) or CDMA (code division multiple access). Next section will dicuss this technique in detail.

Each cluster usese a unique spreading code,where each node in a certain cluster transmit its data to the cluster-head using this spreading code and the cluster-head filters all received energy using this spreading code. All the transmitters within the cluster use the same code. The first cluster-head to advertise its position is assigned the first code on a pre-defined list, the second cluster-head to advertise its position is assigned the second code, etc.

To prevent the corruption of transmission from nodes in the cluster, the neighboring clusters' radio signals will be filtered out as noise during de-correlation, while reduce the possibility of interfering with nearby clusters, and reduce its own energy dissipation itself, each node adjusts its transmitted power. Therefore, there will be few overlapping transmissions and little spreading of the data is actually needed to ensure a low probability of collision.

A singal matched-filter collelator for cluster-head is needed since all the signals destined for it use the same spreading code. This is differs from a CDMA approach where each node would have a unique code and the base station receiver would need a many matched filters to obtain the data. So we can conclude that the benfitsof using DS-SS with a TDMA schedule as mentioned below:

- reduce inter-cluster interference;
- eliminating intra-cluster interference;
- a single matched-filter correlator for the receiving data.

The data from cluster-head to the base station send using fixed spreading code and a GSMA approach. The cluster-head send the data which it has at the end of its frame, but first sense and check if there is another one want transmit as well using the base station spreading code.

**Direct-sequence spread spectrum (DSSS) technique**

In telecommunication, direct-sequence spread spectrum(DSSS) is a spread spectrum modulation technique. Spread spectrum systems are such that they transmit the message bearing signals using a bandwidth that is in excess of the bandwidth that is actually needed by the message signal, but this kind of spreading of the transmitted signal over a large bandwidth make the resulting wideband signal appear as a noise, and that allow greaterresistance to intentional and unintentional interference with the tranmistted signal [25].

One other developed methods of achieving this spreading of the message signal is provided by DSSS modulation. In DSSS the message signal is used to modulate a bit sequence known as the Pseudo Noise (PN) code; this PN code consists of pulses of a much shorter duration(larger bandwidth) than the pulse duration of the message signal, therefore the modulation by the message signal has the effect of chopping up the pulses of the message signal and thereby resulting in a signal which has a bandwidth nearly as large as that of the PN sequence [25].

Some of the uses of DSSS include the Code Division Multiple Access (CDMA) channel access method and the IEEE 802.11b specification used in Wi-Fi networks. [26][27]

The DSSS technique has many features as mentioned below :

– DSSS phase-shifts a sine wave pseudorandomly with a continuous string of pseudonoise(PN) code symbols called "chips", each of which has a much shorter duration than an information bit, where each information bit is modulated by a sequence of much faster chips. Sothat, the chip rate is much higher than the information signal bit rate;

– DSSS uses a signal structre in which the sequence of chips produced by the transmitter isalready known by the receiver. The receiver can then use the same PN sequence to counteract the effect of the PN sequence on the received signal in order to reconstruct the information signal.

The DSSS Direct-sequence spread- spectrum transmissions method multiply the data being transmitted by a "noise" signal. This noise signal is a pseudorandom sequence of 1 and −1 values, at a frequency much higher than that of the original signal.

The resulting signal resembles white noise, like an audio recording of "static". However, this noise-like signal is used to exactly reconstruct the original data at the receiving end, by multiplying it by the same pseudorandom sequence (because $1 \times 1 = 1$, and $-1 \times -1 = 1$). This process, known as "de-spreading", mathematically constitutes a correlation of the transmitted PN sequence with the PN sequence that the receiver already knows the transmitter is using.The resulting effect of enhancing signal to noise ratio on the channel is called process gain.

If an undesired transmitter transmits on the same channel but with a different PN sequence (or no sequence at all), the de-spreading process has reduced processing gain for that signal. This effect is the basis for the code division multiple access(CDMA) property of DSSS, which allows multiple transmitters to share same channel within limits of the cross-correlation of their PN sequnces.[28]

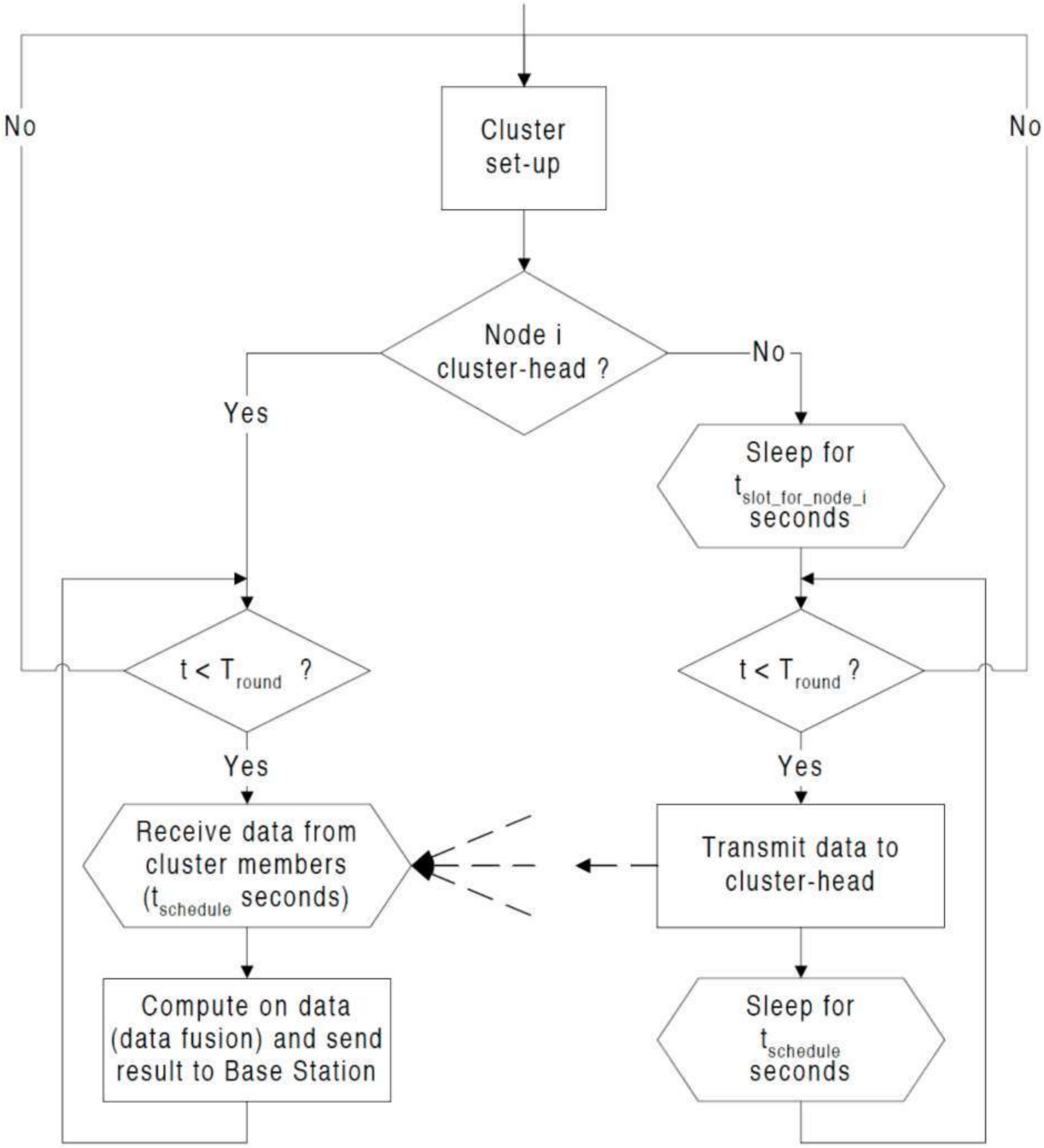


Figure 2.4 – Flow-graph of the steady-state operation for LEACH

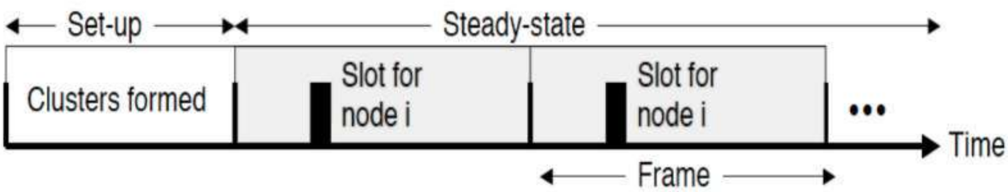


Figure 2.5 – Time-line showing LEACH operation Data transmissions are explicitly scheduled toavoid collisions and increase the amount of time each non-cluster-head node can remain in the sleepstate

**Sensor Data Aggregation**

As the sensor nodes can generate significant amounts of redundant data, similar packets from multiple nodes can be aggregated to reduce the number of transmissions.Data aggregation is the combination of data from different sources according to some aggregation function (eg, removing duplicate, minima, maxima, and average) to produce a meaningful description of events that are occurring in the environment.

In many routing protocols this technique was used to achieve energy efficiency and optimization of data transfer, Signal processing methods can also be used for the same purpose, and will referred to it as data fusion where a node is capable of producing an output signal by using more precise techniques such as beamforming to combine the incoming signals and reduce noise in these signals.

Data aggregation can also be performed on all the unprocessed data at the base station, but if we analytically compare the energy dissipation required to perform data aggregation and send the resultant data to the base station versus sending upprocessed data to the base station. Suppose that

*EDA*is the energy dissipation per bit for data aggregation

*ETX* is the energy dissipation per bit to transmit to the base station

In addition, suppose that the data aggregation method can compress the data with a ratio of *L:1*.

This mean that for every *L* bits that must be sent to the base station without performing the data aggregation, while only 1 bit must be sent to the base station when data aggregation performed locally, mathematically we can explain and prove that as shown below:

$$ELocal{-}DA = LEDA + ETX. \tag{2.5}$$

Equation (2.5) shows the energy to perform local data aggregation and transmit the aggregated signal for every *L* bits of data, and the energy to transmit all *L* bits of data directly to the base station is:

$$Eno{-}DA = LETX. \tag{2.6}$$

We can conclude that, performing local data aggregation requires less energy than sending all unprocessed data to the base station when:

$$\begin{aligned} E_{Local-DA} &< E_{No-DA} \\ LE_{DA} + E_{TX} &< LE_{TX} \\ E_{DA} &< \frac{L-1}{L} E_{TX} \end{aligned} \tag{2.7}$$

To confirm these result, we can calculate that for number of nodes where *N= 20* nodes sent data to the cluster-head in case the data aggregated locally, The cluster-head will require to send only a single signal to the base station *(L=20)*, or all of the unprocessed data are sent to the base station in case data sent to the base station without aggregation, If we consider the base station at distance 100 m away from the cluster-head node, and for single bit the cost for communication is $1{,}05\cdot10^{-6}$ J. Figure (2.6) below shows the total energy dissipated in the system when the aggregated data sent to the base station which already has been aggregated locally versus the dissipation of energy in the sensor system when data send directly the base station without aggregation locally.

As the energy required to perform the data aggregation function varies between 1 Pj/bit/signal and 1 Mj/bit/signal. If the energy to perform data aggregation is less than $(19/20)\cdot1{,}05\cdot10^{-6} \approx 1{,}05\cdot10^{-6}$, the total energy disspated in the system is less using local processing of the data. When the cost of aggregating the signals is higher than 1 μJ/bit/signal, it is more energy-efficient to send the data directly to the base station.[29]

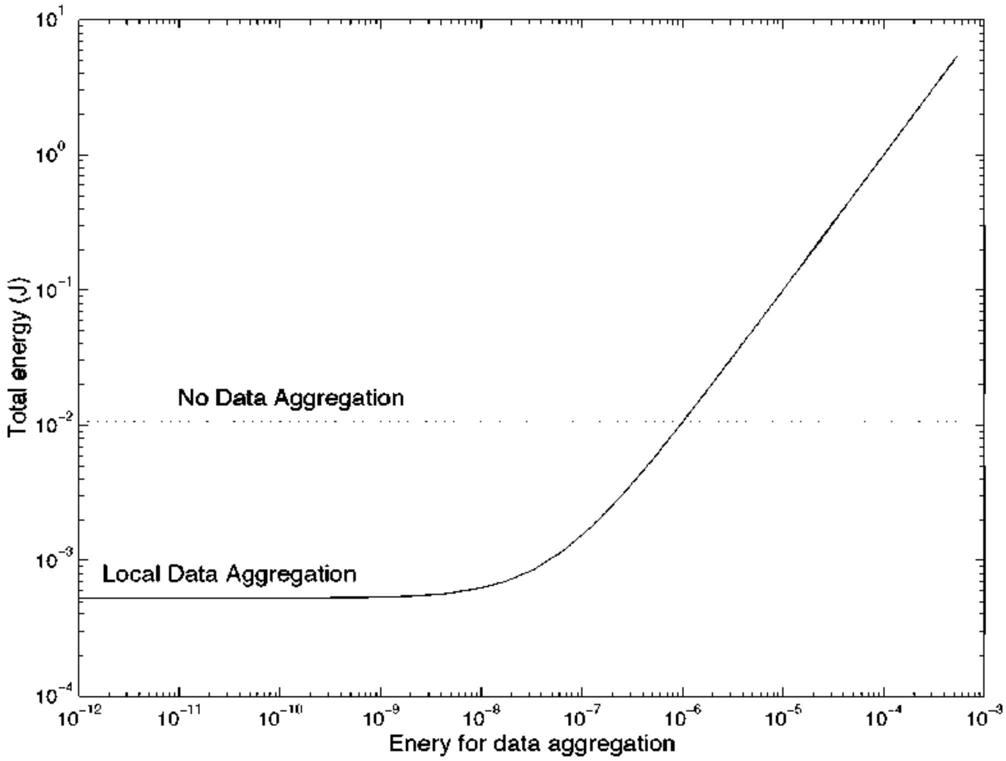


Figure 2.6 – Enery for data aggregation

**Data Correlation**

Communication components consume most of the energy inWSNs. Computation uses less. Therefore, it becomes attractive to deploy data compressiontechniques, which might increase computational energy somewhat, butdecrease the number of packet transmissions:

- usually, the data collected in neighboring sensor nodes are correlated, especially when the deployment of sensor nodes is quite dense in the network;
- due to the treelike logical topology of most WSNs, the correlation may become more apparent on the pathfrom the sensor nodes to the sink;
- the occurrence of an event may be assimilatedwith a continuous-time but random process, and sampling of the random processeshelps extract information content from the process;
- the application semanticmay enable data aggregation or data fusion;
- the tolerance of applicationsfor possible errors in data may make it possible to reduce data reading and reportingfrequencies.[30].

Data correlation is one of the compression techniques, and its very important aggregated all signals from cluster members into a single signal that describes the event seen by all the nodes. LEACH can achievelocal data aggregation from different sensor nodes in order to estimate the amount of compression. If we assume that the source signal travels a distance $\rho$ before it can no longer be reliable detected by the sensors(due to signal attenuation), and that sensors are omnidirectional (e.g., acoustic, seismic sensors), the maximum distance between sensors with correlated data is $2\rho$, as shown in Figure 2-7a, However, being within $2\rho$ ofeach other does not guranteethat the two sensors will detect the same signal (Figure 2-7b). If all nodes are within a cluster of diameter $d$(i.e., the maximum distance between two nodes is $d$) and $d<2\rho$, the views of the individual sensors will overlap.

The amount of correlation determine by first find the percentage of area overlapped by j sensors in order to calculate the probability that a source is detected within the cluster. We could express that as function $f$ which will depend on three paremeters, $\rho$ ,$d$ , and $N$ the total number of node in the cluster, and it will define mathematically as shown below:

$$f(j, N, \rho, d) = \frac{A(j)}{A_{total}}, \tag{2.8}$$

where A(j) is the area overlapped by j and only j sensors' views and

$$A_{total} = \sum_{j=1}^{N} A(j), \tag{2.9}$$

is the total area seen by at least one sensor in the cluster

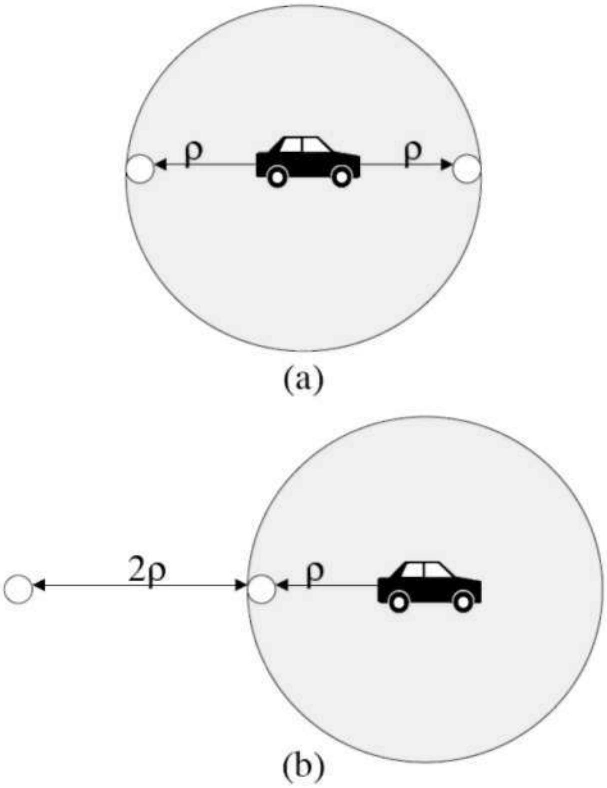


Figure 2.7 – Correlation among data sensed at the nodes. If a source signal travels a distance $\rho$, the maximum distance between correlated data signals is $2\rho$(a). However, nodes can be $2\rho$apart and have uncorrelated data (b).[31]

## 2.4 Analysis and Simulation of LEACH

For even moderately-sized network with tens of nodes, it is impossible to analytically model the interactions between all the nodes. Therefore, simulation was used to determine the benefits of different protocols. Communication and computation energy dissipation models in addition to new MAC algorithum were implemented in Matlab, ns and other computer software to support the design and simulation of many types of protocol architectures. In the experiment described in this chapter, LEACH (rotating clutser-head algorithm) for moderated-sized wireless sensor network is compared with Multi-Hop Dynamic Clustering LEACH Protocol for Large Scale Networks. In this chapter LEACH design and simulation will be describe for the following items:

- system lifetime,
- energy dissipation,
- amount of data transfer and latency

2.4.1 Simulation Models

To make comparisonbetween different protocols, it is important to have their models for all orientation of communication. The current section describes the models that were used for:

– channel propagation;

– communication energy dissipation;

– computation energy dissipation.

**Channel Propagation Model**

In general wireless transmission distort any transmitted signal, and in wireless channel, the electromagnetic wave propagation can be mathematically describe the power disspation is depend on the distance between transmitter and receiver.

We can summarize the sources of distortion:

– attenuation –energy is distributed to larger areas with increasing distance;

– reflection/refraction –bounce of a surface; enter material;

– diffraction –start “new wave” from a sharp edge;

– scattering –multiple reflections at rough surfaces;

– doppler fading –shift in frequencies (loss of center).

Figure below shows some of these distortion sources.

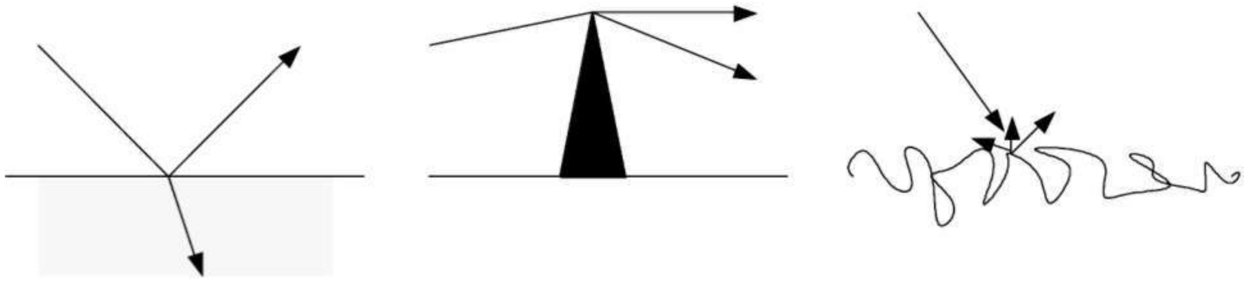

Figure 2.8 – Distortion sources of signal in wireless transmission

The strength of signal depend on the path  between transmitter and receiver, either direct line-of-sight between transmitter and receiver or not direct, so the electromagnetic wave will bounce off object in the environment and arrive at the receiver from different paths at different times.

This causes multipath fading, which again can be roughly modeled as a power law function of the distance between the transmitter and receiver. No matter which model is used (direct line-of-sight or multipath fading), the received power decreases as the distance between the transmitter and receiver increase[32].

In the experiment of this dissertation, both the free space model and multipath fading model were used, depending on the distance between the transmitter and the receiver.

The cross-over point is define as follows:

$$d_{crossover} = \frac{4\pi\sqrt{L}h_r h_t}{\lambda}, \quad (2.10)$$

where $L \geq 1$ is the system loss factor not related to propagation,

$hr$ is the height of the receiving antenna above ground,

$ht$ is the height of the transmitting antenna above ground, and

$\lambda$ is the wavelength of the carrier signal.

A certain cross-over distance called (*dcrossover*), If the distance between transmitter and receiver is less than this distance, or greater than it so we can summarize these two cases as below:

– When the distance is greater than (*dcrossover*), the two-ray ground propagation model is used (*d ^4* attenuation). The Friss free space model is used (*d ^4* attenuation), and the transmitted power is attenuated according to the two-ray ground propagation equation as follows:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4} \quad (2.11)$$

where *Pr(d)* is the receive power given a transmitter_receiver separation of d,

*Pt* is the transmit power,

*Gt* is the gain of the transmitting antenna,

*Gr* is the gain of the receiving antenna,

*hr* is the height of the receiving antenna above ground,

*ht* is the height of the transmitting antenna above ground, and

*d* is the distance between the transmitter and the receiver.

In this case, the received signal comes from both the direct and a ground-reflection path [32].

If the distance between the transmitter and receiver is less than a certain cross_over distance _dcrossover__ the Friss free space model is used _d_

– When the distance is less than *(dcrossover),* the Friss free space model is used(*d* ^2 attenuation), and the transmitted power is attenuated as weel according to the Friss free space equation as follows:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L}, \tag{2.12}$$

where *Pr(d)* is the receive power given a transmitter-receiver separation of *d*,

*Pt* is the transmit power,

*Gt* is the gain of the transmitting antenna,

*Gr* is the gain of the receiving antenna,

λis the wavelength of the carrier signal,

*d* is the distance between the transmitter and the receiver, and

*L*≥ is the system loss factor not related to propagation.

Equation (2-12) models the attenuation when the transmitter and receiver have direct, line-of-sight communication, which occur only when they transmitter and receiver are close to each other (i.e., *d*<*dcrossover).*

**Radio Energy Model**

All the new researches in the area of low-energy radios cover all these assumption about the radio characteristics, including energy dissipation in the transmitter and receiver mode, will make positive changes in different protocols. In this work, we will assume a simple model where the transmitter dissipates energy to run the radio electronic and the power amplifier and the receiver dissipated energy to run the radio electronics[33], figure below show a simple block diagram of radio energy dissipation model.

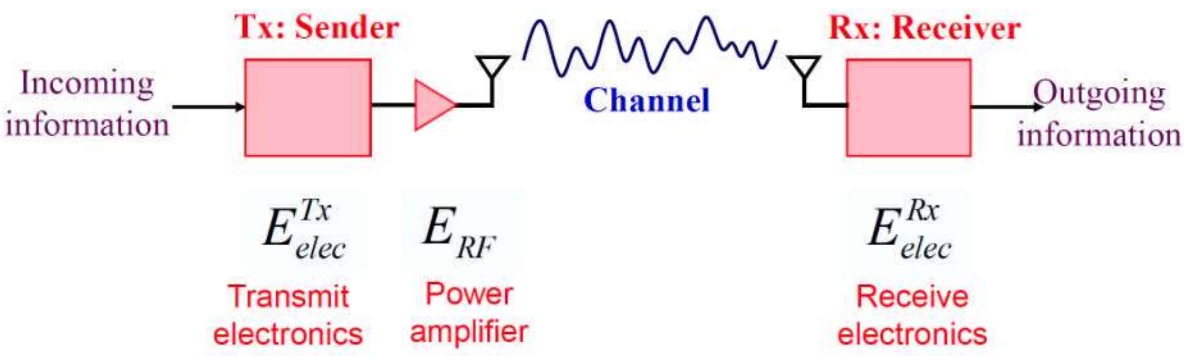


Figure 2.9 – Block diagram of radio energy dissipation model

In the previous section we discuss the power attenuation with formula and we see how is the power depend on the distance between the transmitter and receiver. we can summarize in two propational cases:

- At short distances, the loss due to propagation can be modeled as inversely proportional to *d^2*.
- At long distances, the loss due to propagation can be modeled as inversely proportional to *d^4*.

To controlling this loss a power control can be used to invert this loss by setting the power amplifier to ensure a certain power at the receiver.

So to transmit an *l*-bit message a distance *d*, the radio expends:

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d) \quad (2\text{-}13)$$

$$E_{Tx}(l,d) = \begin{cases} lE_{elec} + l\epsilon_{friss-amp}d^2 & : \quad d < d_{crossover} \\ lE_{elec} + l\epsilon_{two-ray-amp}d^4 & : \quad d \geq d_{crossover} \end{cases} \quad (2\text{-}14)$$

and to receive this message, the radio expends.

$$E_{Rx}(l) = E_{Rx-elec}(l)$$
$$E_{Rx}(l) = lE_{elec} \quad (2.15)$$

as shown in figure(2.9).

The electronics energy, *Eele*depends on factors such as the digital coding, modulation, and filtering of the signal before it is sent to the transmit amplifier. Aslo, when using DS-SS, the electronics energy accounts for the spreading of the data when the transmitting and the correlation of the data with the spreading code when receiving. Due to many researchers interest and make many researches in this field, they intend to design transceiver baseband chips that support multi-user speard-spectrum communication and operate at 165 Mw in transmit mode and 46.5 Mw in receive mode [34].

The experiments described in this dissertation, the energy dissipated per bit in the transceiver electronics will be set to be

$$Eele = 50 \text{ Nj/bit} \tag{2.16}$$

So for a 1Mpbs transceiver. The radio electronics dissipated will be 50 Mw when there is an operation (either transmit or receive).

The paremeters $\epsilon$*friss-amp* and $\epsilon$*two-ray-amp* will depend on the required receiver sensitivity and the receiver noise figure, as the transmitter power needs to be adjusted so that the power at the receiver is above a certain threshold, *Pr-thresh*. To determine the minimum transmit power we can figure out it from the received power threshold. If the radio bit rate is *Rb*, the transmit power, *Pt*is equal to the transmit energy per bit *ETx-amp(1,d)* times per bit rate:

$$P_t = E_{Tx-amp}(1,d)R_b \tag{2-17}$$

Plugging in the value of *ETx-amp(1,d)* gives:

$$P_t = \begin{cases} \epsilon_{friss-amp}R_b d^2 & : \quad d < d_{crossover} \\ \epsilon_{two-ray-amp}R_b d^4 & : \quad d \geq d_{crossover} \end{cases} \tag{2-18}$$

Using the channel models described in the previous section, the received power is:

$$P_r = \begin{cases} \frac{\epsilon_{friss-amp}R_b G_t G_r \lambda^2}{(4\pi)^2} & : \quad d < d_{crossover} \\ \epsilon_{two-ray-amp}R_b G_t G_r h_t^2 h_r^2 & : \quad d \geq d_{crossover} \end{cases} \tag{2.19}$$

The parameters $\epsilon$*friss-amp* and $\epsilon$*two-ray-amp* can be determined by setting Equation 2.19 equal to *Pr-thresh*:

$$\epsilon_{friss-amp} = \frac{P_{r-thresh}(4\pi)^2}{R_b G_t G_r \lambda^2} \tag{2.20}$$

$$\epsilon_{two-ray-amp} = \frac{P_{r-thresh}}{R_b G_t G_r h_t^2 h_r^2} \tag{2.21}$$

Therefore, the required transmitted power, *Pt,* as a function of the receiver threshold and the distance between the transmitter and receiver is:

$$P_t = \begin{cases} \alpha_1 P_{r-thresh} d^2 & : \quad d < d_{crossover} \\ \alpha_2 P_{r-thresh} d^4 & : \quad d \geq d_{crossover} \end{cases} \tag{2.22}$$

$$\text{where } \alpha_1 = \frac{(4\pi)^2}{G_t G_r \lambda^2} \text{ and } \alpha_2 = \frac{1}{G_t G_r h_t^2 h_r^2}.$$

Threshold P*r-thresh*can be determined by give estimated value for the noise at the receiver . If the thermal noise floor is 99 dBm[35], and the receiver noise figure is 17 Db^2, and a signal-to-noise ratio(SNR) we will be required of at least 30 Db to receive the signal without error, for successful reception is the minmum receive power P*r-thresh*is

$$P_{r-thresh} \geq 30 + (-82) = -52 \text{ dBm} \tag{2.23}$$

Therefore, for successful reception of the packet, the received power must be at least -52 dBm or 6.3 Nw, plugging the values that will be used in the expermints (Gt=Gr=1, ht=hr=1.5m, λ=328 m, and Rb= 1Mbps) into equations 2.20 and 2.21 gives

$$\epsilon_{friss-amp} = 10 \text{ pJ/bit/m}^2 \tag{2.24}$$

$$\epsilon_{two-ray-amp} = 0.0013 \text{ pJ/bit/m}^4 \tag{2-25}$$

These two values will be used in the simulation by Matlab which will descried later in this chapter.

**Beamforming Energy Model**

The result of experiment described in[36] were usedto model the computational costs ofperforming beamforming data aggregation. Alice Wang ran experiments implementing the least mean square(LMS) and Maximum Power beamforming algorithms on a strongARM processor and measured the energy dissipation. Figure 2.10 shows the result of these experiments.

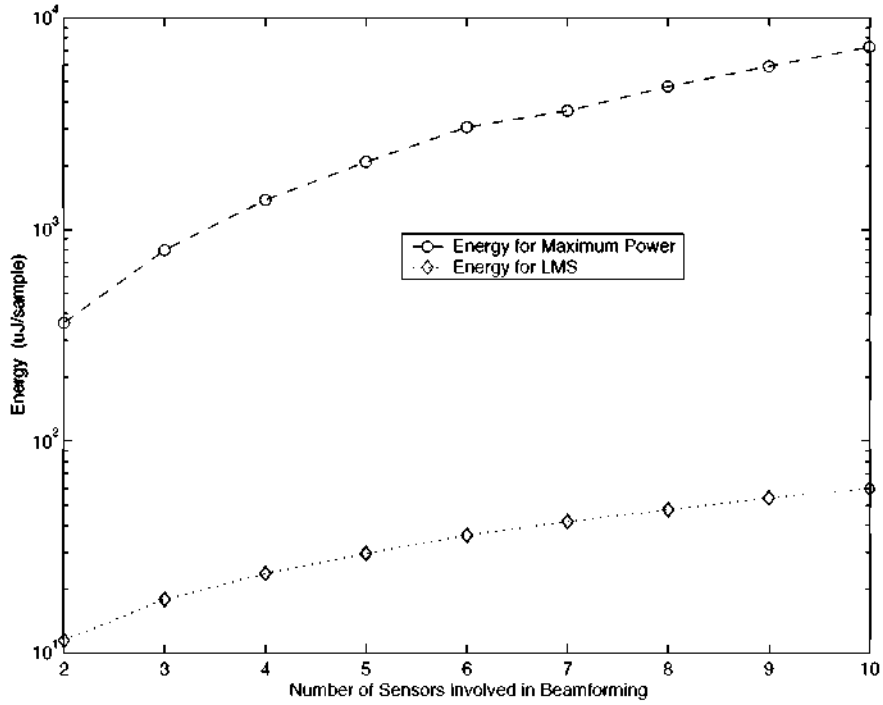


Figure 2.10

From figure we can conclude that:

- LMS beamforingalogorithum requires much less energy than the Maximum power beamforingalgorthim.
- LMS beamforming energy scales linearly with the number of sensors.
- Maximum Power beamforming scales quadratically scales with the number of sensors.
- LMS beamforming algorithm is better suitable for implementation on a law-power microsensor node.

Figure 2.10 shows that implementation the LMS beamforming algorithmrequire 5 µJ/ sample/signal, or 625 Nj/bit/signal, To obtain preciselyaccepatable results the (ASIC) will be used in implemention of beamforming algorithm, so the computation energy for beamforming BF will be setted to 5 Nj/bit/signal in our experiments and all related parameters can be summarize in table 2.1 below

Table 2.1 – Radio characeteristics and parameters values

| Description | Parameter | Value |
|---|---|---|
| Cross-over distance for Friss and two-ray ground attenuation models | $d_{crossover}$ | $\frac{4\pi h_r h_t}{\lambda}$ |
| Transmit power | $P_t$ | $\epsilon_{friss-amp} R_b d^2 \quad : \quad d < d_{crossover}$<br>$\epsilon_{two-ray-amp} R_b d^4 \quad : \quad d \geq d_{crossover}$ |
| Receive power | $P_r$ | $\frac{\epsilon_{friss-amp} R_b G_t G_r \lambda^2}{(4\pi)^2} \quad : \quad d < d_{crossover}$<br>$\epsilon_{two-ray-amp} R_b G_t G_r h_t^2 h_r^2 \quad : \quad d \geq d_{crossover}$ |
| Minimum receiver power needed for successful reception | $P_{r-thresh}$ | 6.3 nW |
| Radio amplifier energy | $\epsilon_{friss-amp}$<br>$\epsilon_{two-ray-amp}$ | $\frac{P_{r-thresh}(4\pi)^2}{R_b G_t G_r \lambda^2}$<br>$\frac{P_{r-thresh}}{R_b G_t G_r h_t^2 h_r^2}$ |
| Radio electronics energy | $E_{elec}$ | 50 nJ/bit |
| Compute energy for beamforming | $E_{BF}$ | 5 nJ/bit |
| Bitrate | $R_b$ | 1 Mbps |
| Antenna gain factor | $G_t, G_r$ | 1 |
| Antenna height above the ground | $h_t, h_r$ | 1.5 m |
| Signal wavelength | $\lambda$ | 0.325 m |
| Cross-over distance for Friss and two-ray ground attenuation models | $d_{crossover}$ | 87 m |
| Radio amplifier energy | $\epsilon_{friss-amp}$<br>$\epsilon_{two-ray-amp}$ | 10 pJ/bit/m$^2$<br>0.0013pJ/bit/m$^4$ |

## 2.5 Modelling Set-up and Simulation Results

Implementation of wireless sensor network modeling by using Matlab software from MathWorks company, we have 100- sensor nodes, randomly distributed in a square area 100 m x 100 m, the base station (Sink)located in the middle of the area exactly at point with cooridnates (50,50).

Below Table 2.2 shows some network characteristics

Table 2.1– Characteristics of the sensor networkEnviroment

| Paremeters | Value |
|---|---|
| No of. Nodes | 100 |
| Network size | 100 m x 100 m |
| Base station location | ( 50 , 50 ) |

Extension Table 2.1

| Paremeters | Value |
|---|---|
| Radio propagation speed | 3x 10^8 m/s |
| Processing delay | $50\mu s$ |
| Initial Energy | 0.5 J |
| m (probability to be advanced node) | 0.1 |
| Radio speed | 1 Mbps |
| Data size | 4096 bytes |

As like any other modeling and experiments there are Some assumptions about the sensor nodes and the underlying network in general as we will described them below:

- the Network is homogeneous that all nodes have equal initial energy at the time of deployment;
- the Network is static and nodes are distributed randomly;
- there exists only one base station, which is placed in the middle (50,50);
- the Energy of sensor nodes cannot be recharged after deployment of network;
- sensor nodes are equipped with GPS so aware about their location;
- no power and computational constraints in Base- Station (BS);
- deployed Nodes can use power control to vary the amount of transmission power, which depends on the distance to the receiver.

We have used the radio energy model as shown in block diagram below, which uses a 914 MHz radio.

Table 2.2 give a summary for enviroments parameters such like:

- processing delay has been set to 25 μs on both side the transmitter and receiver;
- Length of the data message 500 bytes, while packet header length 25 bytes for every type of packets;
- Setting 50 Nj/ bit for the radio electronics energy;
- Setting 10 Pj/bit/m^2if the distance less than 87 m, and 0.0013 Pj/bit/m^4for distance greater

than 87 m;

- 5 Nj/bit/signal energy has been setted for the purpose of beamforming computation performing;
- The optimum numbers of clusters can be calculated 38hreshold38ally according to the energy models mentioned in the previous section.

Suppose with *N* number of node has been distributed in an *LX W* square area, and the number of clusters *K* will be as average quotient of *N/K*(number of nodes per cluster).And we developed our LEACH protocol where each node has an opportunity to be a cluster-head, so we can calculate the estimated cluster-head energy dissipation for the node when take the role of being a cluster head, receiving signals from nodes, beamforming and processing, then send the aggregated data to the base station (sink), may be sink location is not near this cluster-head, as we mentioned in the previous section that cross-over distance, so if the distance from cluster-head to the sink is greater than cross-over distance the dissipation of energy will follows the model of two-ray ground (e.g., *d^4*power loss). And the dissipated energy of cluster-head during one frame will be equal to value according to this equation:

$$E_{CH} = lE_{elec}\frac{N}{k} + lE_{BF}\frac{N}{k} + l\epsilon_{two-ray-amp}d^4_{toBS} \tag{2-26}$$

*l* represent the number of bits in each data message.

*DtoBS* represent the distance between cluster-head and sink.

While the energy dissipated for non-cluster-head node will be needed for transmission the data to its cluster-head during the frame. So according to Friss free space model (e.g., *d^2*power loss).So the energy has been used by each non-cluster-head node will be:

$$E_{non-CH} = lE_{elec} + l\epsilon_{friss-amp}d^2_{toCH} \tag{2-27}$$

*d toCH* represent the distance between node and cluster-head.Area of the cluster-head will be (*LXW* )/*k*. take in consideration that the area is square (length = width ) and suppose that the distance from cluster-head to nodes approximately toward the centre of mass so the equation algebraically will be:

$$
\begin{aligned}
E[d_{toCH}^2] &= \int\int (x^2+y^2)\rho(x,y)dxdy \\
&= \int\int r^2\rho(r,\theta)rdrd\theta
\end{aligned}
\tag{2-28}
$$

that's mean the area is a circle has radius *R=(M/√(πk))*and *p(r,φ),* substitute it in equation2-28 will be :

$$
\begin{aligned}
E[d_{toCH}^2] &= \rho\int_{\theta=0}^{2\pi}\int_{r=0}^{\frac{M}{\sqrt{\pi k}}} r^3 drd\theta \\
&= \frac{\rho}{2\pi}\frac{M^4}{k^2}
\end{aligned}
\tag{2-29}
$$

and nodes density are evenly distributed over the cluster area , so *p=1/(LXW/K)*and

Geometric shapes the square L=W we can replace them by one variable M( L=W=M), sothat the area of the square will be M^2.

And substitutein the rest equations so:

$$
E[d_{toCH}^2] = \frac{1}{2\pi}\frac{M^2}{k}
\tag{2-30}
$$

So,

$$
E_{non-CH} = lE_{elec} + l\epsilon_{friss-amp}\frac{1}{2\pi}\frac{M^2}{k}
\tag{2-31}
$$

During the frame of the cluster the energy dissipated will be

$$
E_{cluster} = E_{CH} + \frac{N}{k}E_{non-CH}
\tag{2-32}
$$

The frame total energy

$$
\begin{aligned}
E_{total} &= kE_{cluster} \\
&= l(E_{elec}N + E_{BF}N + k\epsilon_{two-ray-amp}d^4_{toBS} + NE_{elec} + N\epsilon_{friss-amp}\frac{1}{2\pi}\frac{M^2}{k})
\end{aligned}
$$

(2-33)

By taking the derivative of *Etotal*with respect to *k* to zero:

$$
\begin{aligned}
\frac{dE_{total}}{dk} &= 0 \\
\epsilon_{two-ray-amp}d^4_{toBS} &= N\epsilon_{friss-amp}(\frac{1}{2\pi}\frac{M^2}{k^2}) \\
k &= \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\epsilon_{friss-amp}}{\epsilon_{two-ray-amp}}}\frac{M}{d^2_{toBS}}
\end{aligned}
$$

(2-34)

in our simulation N=100 nodes, M=100 m, $\epsilon$*friss-amp*=10 Pj, and$\epsilon$*two-ray-amp*=0.0013 Pj, So the expected optimum number of clusters will be

1< k < 6 (2-35)

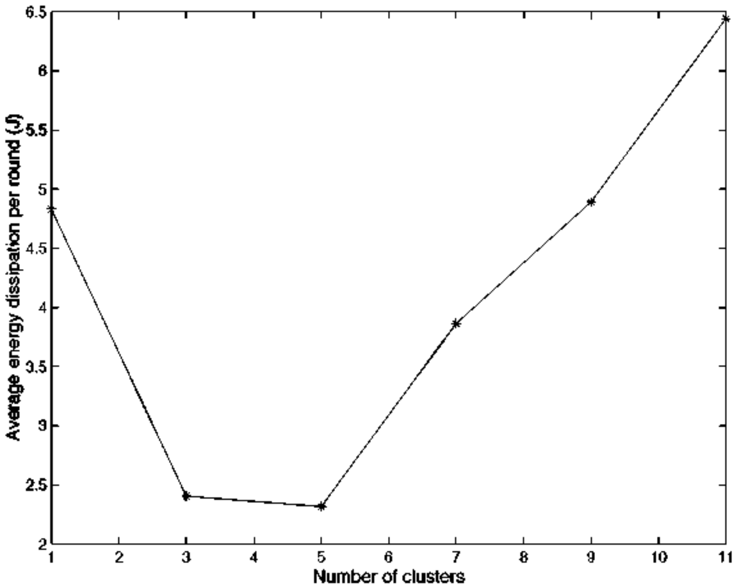


Figure 2.11– shows LEACH energy dissipation per round when the number of clusters varied between 1and 11. Itsobviously shows that LEACH has most energy-efficient between 3 and 5 clusters with network has 100 sensor nodes.

Algorithm LEACH protocol by Matlab_R2016a

```
clc;
clear all;
close all;
%Field Dimensions – x and y maximum (in meters)
xm=100;
ym=100;
%x and y Coordinates of the Sink(base station)
BS.x=0.5*xm;
BS.y=0.5*ym;
n=100; %Number of Nodes in the field
%Energy Model (all values in Joules)
%Initial Energy given to each node
Eo=0.5;
%Data Aggregation Energy
EDA=5*0.000000001;  %5 nJoul
%Transmit Amplifier types
Eelec=70*0.000000001;   %70 nJoul
Eamp=120*0.000000000001;  % 120 pJoul
%maximum number of rounds
rmax=1000;
%Optimal Election Probability of a node
%to become cluster head
p=0.05;
%Percentage of nodes than are advanced
m=0.1;
a=1;
S(n+1).xd=BS.x;
S(n+1).yd=BS.y;
k=4096;
%Creation of the random Sensor Network
figure(1);
fori=1:1:n
S(i).xd=rand(1,1)*xm;
S(i).yd=rand(1,1)*ym;
S(i).G=0;
S(i).type=’N’;
temp_rnd0=i;% ??
%Random Election of Normal Nodes
if (temp_rnd0>=m*n+1)
S(i).E=Eo;
S(i).ENERGY=0;
plot(S(i).xd,S(i).yd,’g*’);
xlabel(‘x dimention’);
ylabel(‘y dimention’);
hold on;
end
```

```
%Random Election of Advanced Nodes
if (temp_rnd0<m*n+1)
S(i).E=Eo*(1+a);
S(i).ENERGY=1;
plot(S(i).xd,S(i).yd,'r*');
hold on;
end
end
S(n+1).xd=BS.x;
S(n+1).yd=BS.y;
plot(S(n+1).xd,S(n+1).yd,'kx','LineWidth',2,'MarkerSize',20); % plot Base Station
figure(2);
cluster=1;
x=0;
for r=0:1:rmax
r
if(mod(r, round(1/p) )==0)
fori=1:1:n
S(i).G=0;
S(i).cl=0;
end
end
hold off;
%Number of dead nodes
dead=0;
%Number of dead Advanced Nodes
dead_a=0;
%Number of dead Normal Nodes
dead_n=0;
figure(2);
fori=1:1:n
if (S(i).E<=0)
% checking if there is a dead node or active node or normal node
% by comparing the energy of each node
plot(S(i).xd,S(i).yd,'k*');
dead=dead+1;
if(S(i).ENERGY==1)
dead_a=dead_a+1;
end
if(S(i).ENERGY==0)
dead_n=dead_n+1;
end
hold on;
end
if(S(i).E>0)
S(i).type='N';
if (S(i).ENERGY==0)
plot(S(i).xd,S(i).yd,'m*');
end
if (S(i).ENERGY==1)
plot(S(i).xd,S(i).yd,'g+');
```

```
end
hold on;
        end
        end
        plot(S(n+1).xd,S(n+1).yd,'kx','LineWidth',2,'MarkerSize',20); % Base station
        STATISTICS(r+1).DEAD=dead;
        DEAD(r+1)=dead;          % first node death FND at rth round
        DEAD_N(r+1)=dead_n;
        DEAD_A(r+1)=dead_a;
        alive(r+1)=100-dead;
        %When the first node dies
        if (dead==1)
        if(x==0) % why =1
        first_dead=r    % first node death END
        x=1;
        end
        end
        %countCHs=0;
        cluster=1;
        fori=1:1:n
        if(S(i).E>0)
        temp_rand=rand;   % radom number generate by node
        if( (S(i).G)<=0)
        %Election of Cluster Heads using the 43hreshold equation
        if(temp_rand<= (p/(1-p*mod(r,round(1/p)))))
        S(i).type='C';
        S(i).G=round(1/p)-1;   % set of nodes that have not been CH
        C(cluster).xd=S(i).xd;
        C(cluster).yd=S(i).yd;
        plot(S(i).xd,S(i).yd,'k*');
        distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 ); % distance of CH from BS
        C(cluster).distance=distance;
        C(cluster).id=i;
        cluster=cluster+1;
        Etx(i)=(Eelec+Eamp*distance*distance)*k;
        S(i).E=S(i).E-Etx(i)-EDA;
        end
        end
        end
        end
        fori=1:1:n
        if( S(i).type=='N'&& S(i).E>0 )
        if(cluster-1>=1)
        min_dis=sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2 );
        min_dis_cluster=1;
        for c=1:1:cluster-1
        temp=min(min_dis,sqrt( (S(i).xd-CI.xd)^2 + (S(i).yd-CI.yd)^2 ) );
        if( temp<min_dis )
        min_dis=temp;
        min_dis_cluster=c;
```

```
end
end
min_dis;
%calucating energies
Etx(i)=(Eelec+Eamp*min_dis*min_dis)*k;
S(i).E=S(i).E-Etx(i);
if(min_dis>0)
Erx=Eelec*k;
S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- (Erx + EDA);
end
S(i).min_dis=min_dis;
S(i).min_dis_cluster=min_dis_cluster;
end
end
end
hold on;
energy=0;
fori=1:n
energy=energy+S(i).E;
end
residue_energy(r+1)=energy;
end
for i=1:1:rmax+1
q(i)=i;
end
figure(3);
plot(q,DEAD);
title('dead nodes');
figure(4);
plot(q,residue_energy);
title('Residual energy');
figure(5);
plot(q,alive);
title('Alive nodes');
DEAD(rmax);
first_dead
```

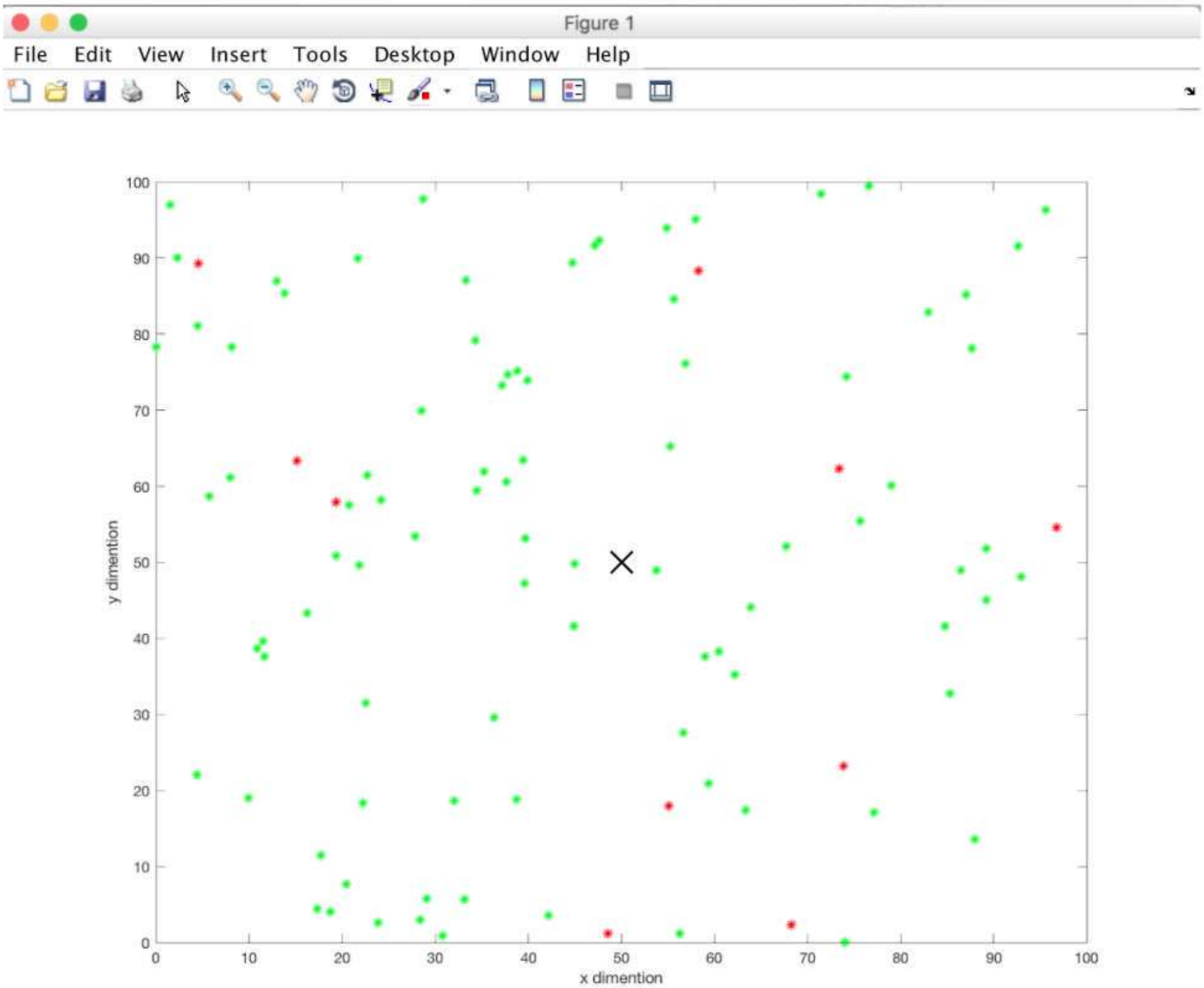
Figure 1
File Edit View Insert Tools Desktop Window Help
y dimention
x dimention
0
10
20
30
40
50
60
70
80
90
100

Figure 2.12

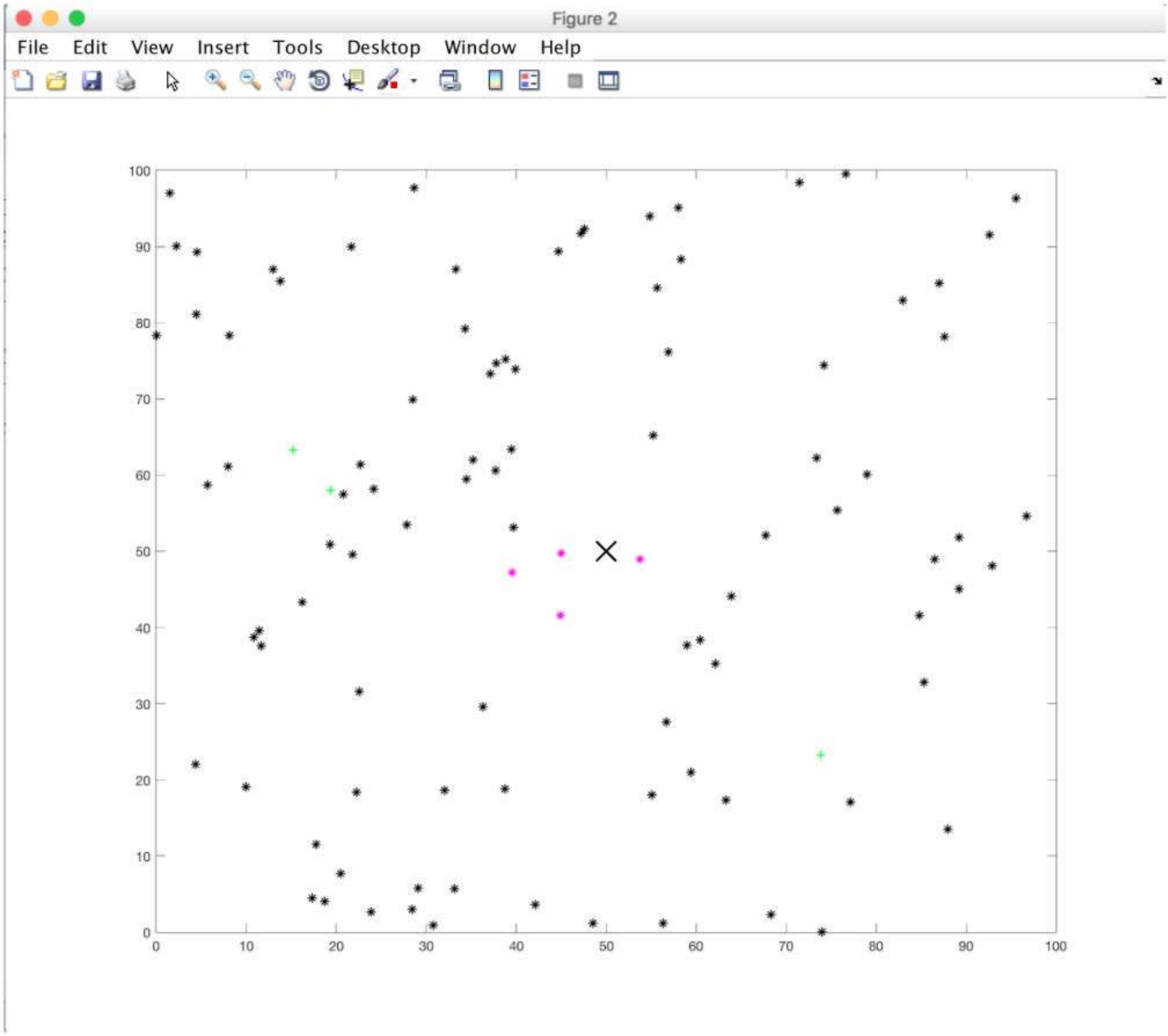
Figure 2
File Edit View Insert Tools Desktop Window Help
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100

Figure 2.13

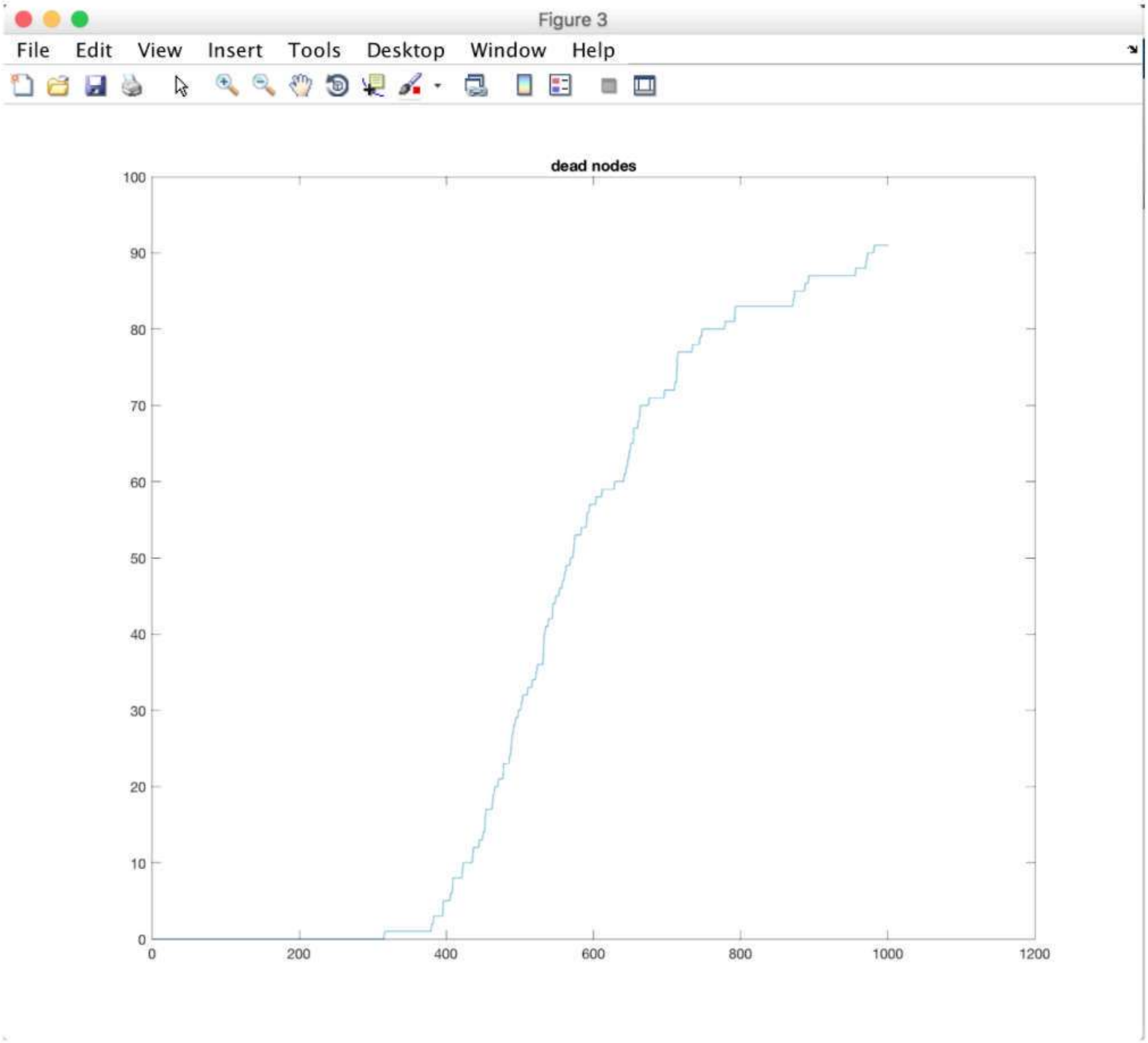

Figure 3
File Edit View Insert Tools Desktop Window Help
dead nodes
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200


Figure 2.14

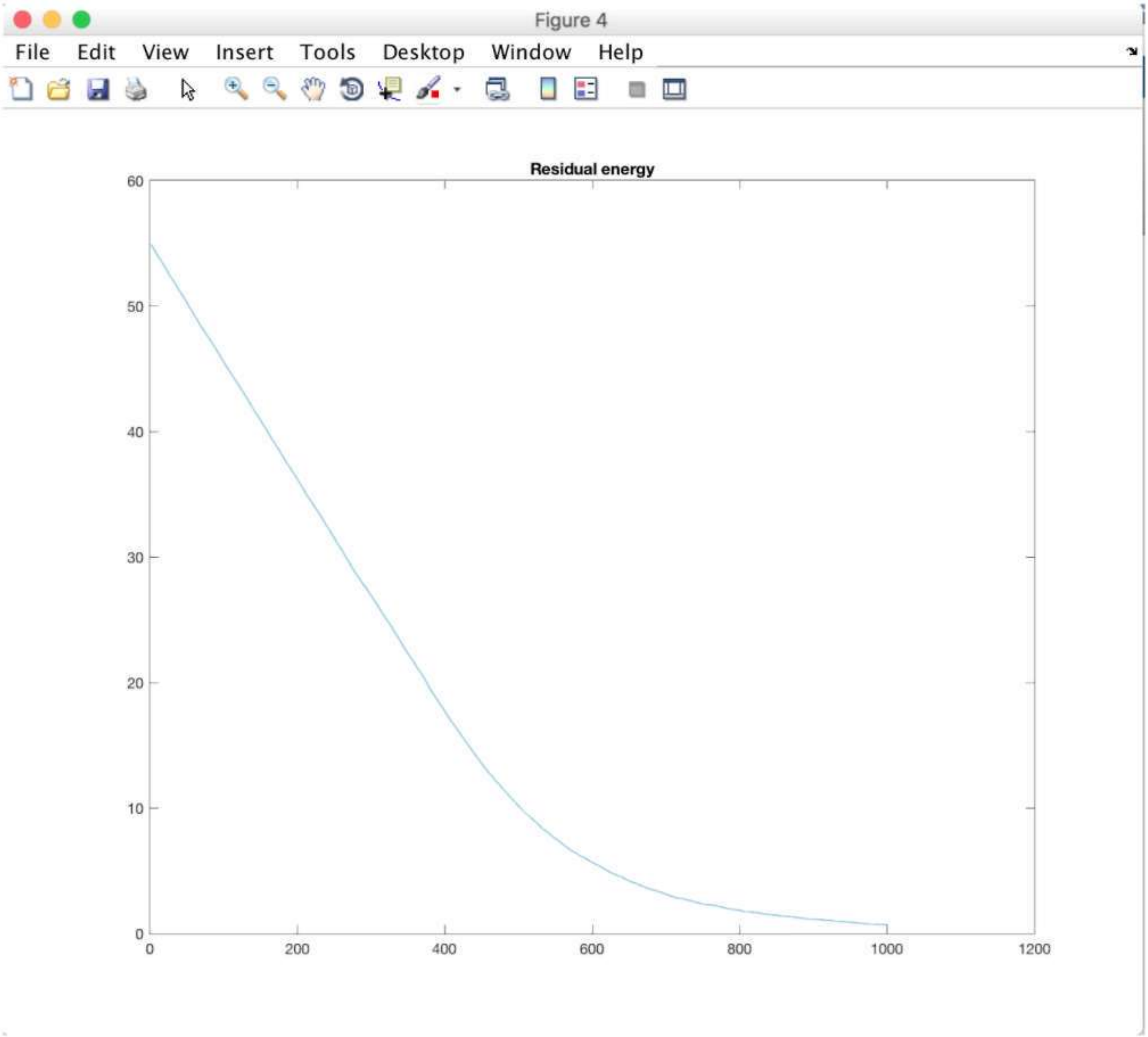
Figure 4
File
Edit
View
Insert
Tools
Desktop
Window
Help
Residual energy
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200

Figure.2.15

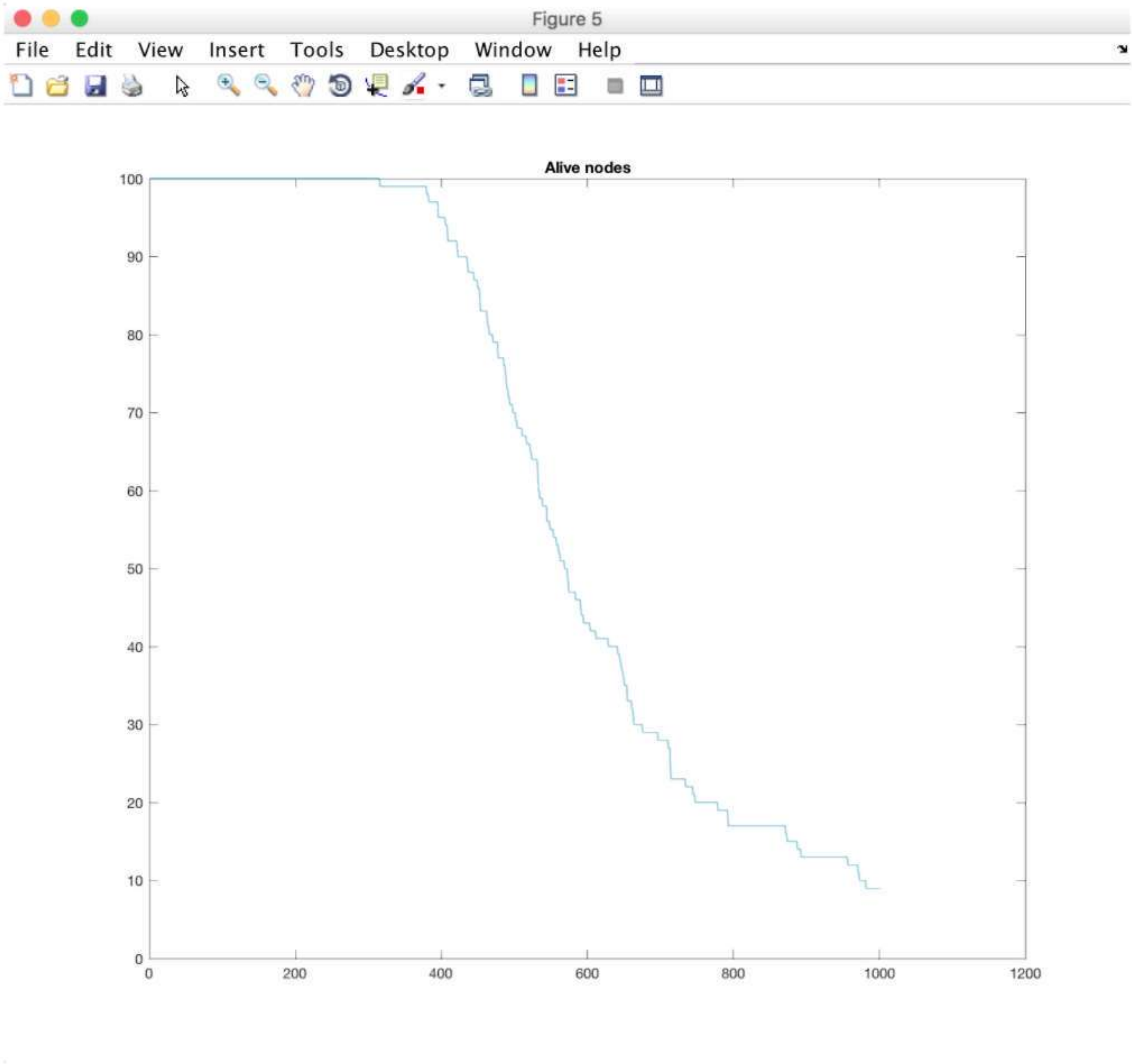
Figure 5
File Edit View Insert Tools Desktop Window Help
Alive nodes
100
90
80
70
60
50
40
30
20
10
0
0 200 400 600 800 1000 1200

Figure 2.15

3 Multi-hop LEACH Protocol Architecture

In the previous chapter we show a full description for implementation and modeling LEACH by Matlabsoftware, and make a good development for selection of cluster-hear in LEACH protocol to make the consumption of energy evenly distributed for all nodes, but make all the nodes have opportunity to became a cluster-head and take all the roles of being cluster-head such like, aggregated data, processing them and send them to the base-station, that will make the nodes will die in the same time, and make the life-time of wireless sensor network larger.

In this chapter will explain another type of LEACH called Multi-hop LEACH which mostly used in large area, where there is sending information between nodes and cluster-head from one side, and sending the information to the base station from another side. Where hoping will be a short path to send the information.

So Multihop-LEACH is a cluster based routing protocol where self-election cluster heads, collect data from the sensors, aggregate them by data fusion method and send them to the sink, and from the path of sending data to the base station the name of protocol came from, or in another way sending the data from sensor node, to the cluster-head, then send them to sink the path will have hopes (steps of path) figure 3.1 shows a simple representation of Multi-hop LEACH protocol.

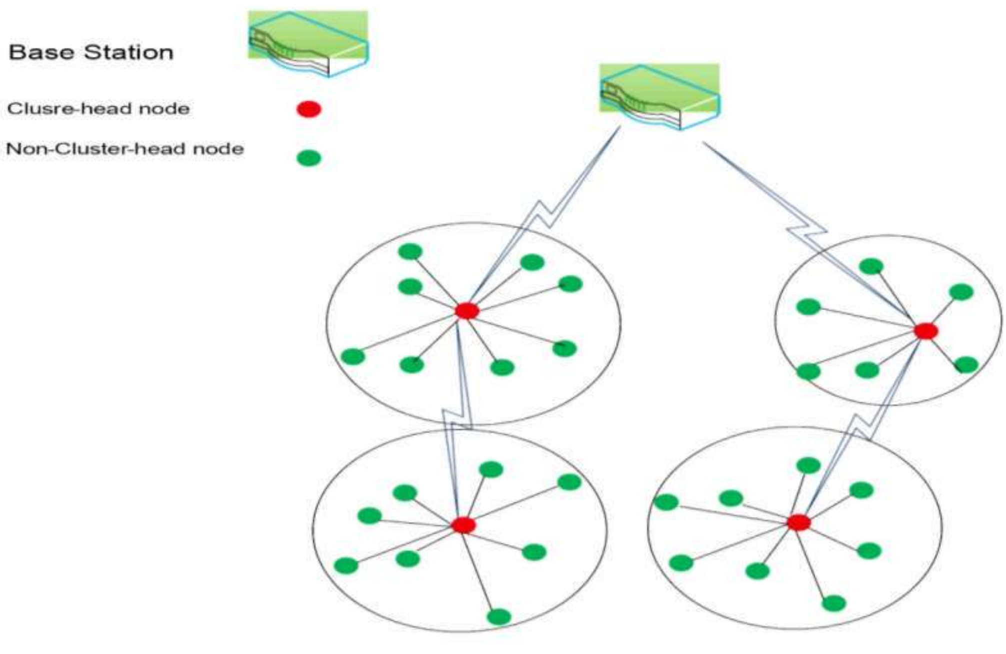


Figure 3.1 –Multi-hop LEACH

As we mentioned in preivious chapter there are two phases for LEACH protocol in general regardless what kind of LEACH is that. Here we have also set up and steady-state phase. Below a flow chart gave quiet enough representation for both phases

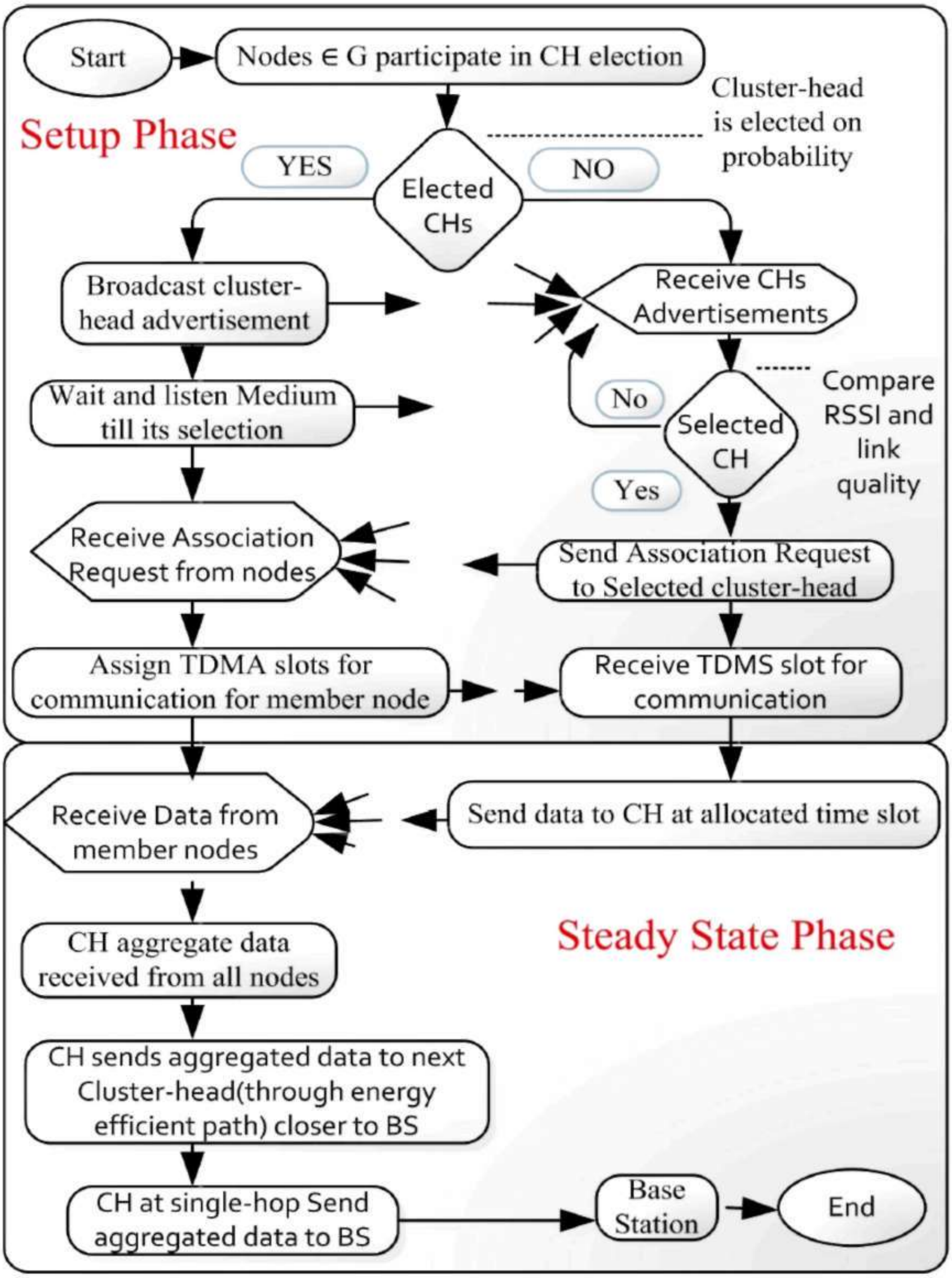


Figure 3.2 –Flow chart of Multi-hop LEACH routing protocol

The purpose behind developing LEACH protocol to multi-hop can be summarize:

- Prolong network life-time by decrease the power consumption due to communicate between node, cluster head and sink;
- Data packet send from the farthest to the nearest cluster-head to the base-station. Figure (3-3) shows a simple digram for that.

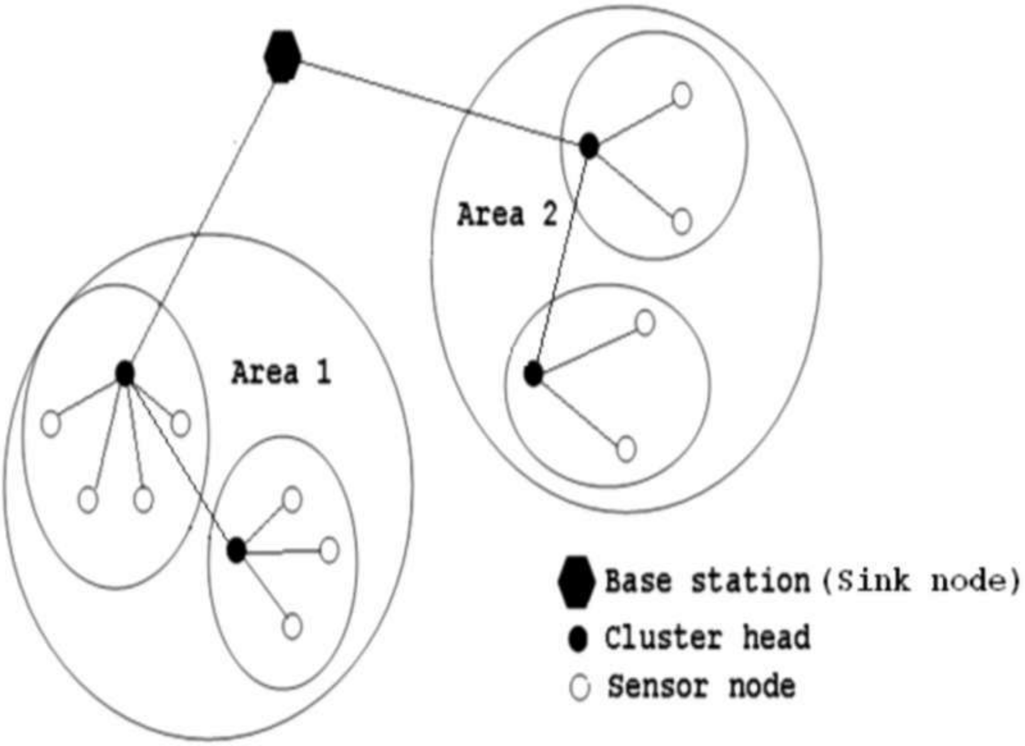


Figure 3.3 –Nodes communicate to Base Station through an optimal path of Cluster Heads in Multi-Hop LEACH protocol

So MH-LEACH use the same mechanism to select the cluster-head, but with two stage the process of collect data as will be summarize below:

- Inter-cluster communication, at this stage the network will divided into several clusters, each has cluster head work on processing these data received from the rest node, aggregate them and send them to the sink;
- Intra-cluster communication, at this stage the nodes send their own data to the rest nodes till amount to cluster-head. Figure (3-4) shows Intra-cluster one-hop and multi-hop connectivity.

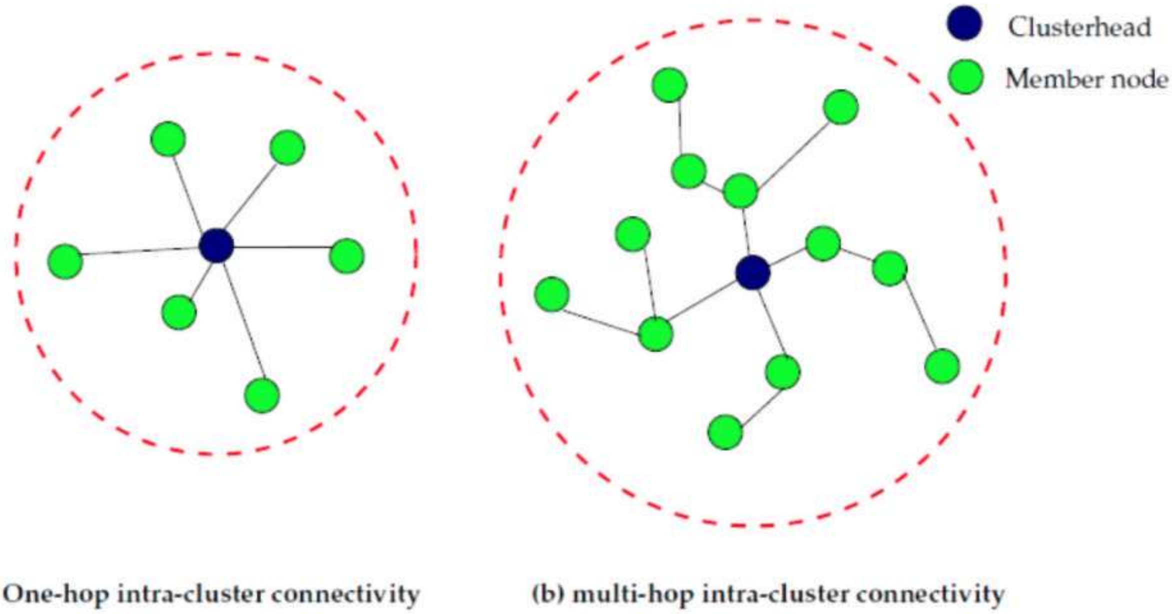


Figure 3–4 Intra – Cluster Connectivity in Multi-hop connectivity

MH-LEACH works  with round  exactly the same of LEACH, but the take a path with minimum hops in between the cluster-head and the sink.

3.1 Self-Configuration Cluster Formation

MH-LEACH is similar to LEACH the organization andformation of clusters take place in the set-up phase[38].Within one transmission radius all the nodes within it broadcast message for example can be set to 'HELLO' during programming, the sequence of broadcasting will be as below steps:

- after the formation of cluster, sensor node will save the cluster-head ID and the rest data will be ignored;
- Cluster-head should has the highest residual energy, if it already has it, will elects itself as a CH;
- A final step aslo message broadcasting, but this time for header, so may be more suitable if its will be set such like (HEAD_MSG);
- Multiple head messages aslo may be broadcasted in the same time, but the nodes will choice the CH whose has the highest Received Signal Strength Identity RSSI;
- Status for non-cluster head node will change to"Members",and cluster-head nodes to "Cluster Head".

Almost the Multihop-LEACH protocol is the same as LEACH protocol only difference in:

– the Communication mode will multi-hop instead of single-hop between cluster-head and sink;

– within one round consider as multi-hop routing algorithm;

– for many last years, the researchers has been divided into two group with regards their opinion for energy consumption for single-hop and multi-hoprouting, some of them assume that single-hop consumption energy less[38] others have claimed the opposite[39][40];

– recently, has been found that the consumption of energy within distance range between source and destination, so single-hop almost more power efficient than multi-hop routing. Its mean after several hops the reliability at mote became insufficient. In addition to subdivide the network to tiers;

– multihop always used when distance between node and sink large and the deployed zone not small, average or large, but there is nogateway or hubs within range;

– always Multi-hop LEACH use in health applications, and wireless sensor network used for military purposes.

– figure 3.5 show a simple representation for single and multiple hops.

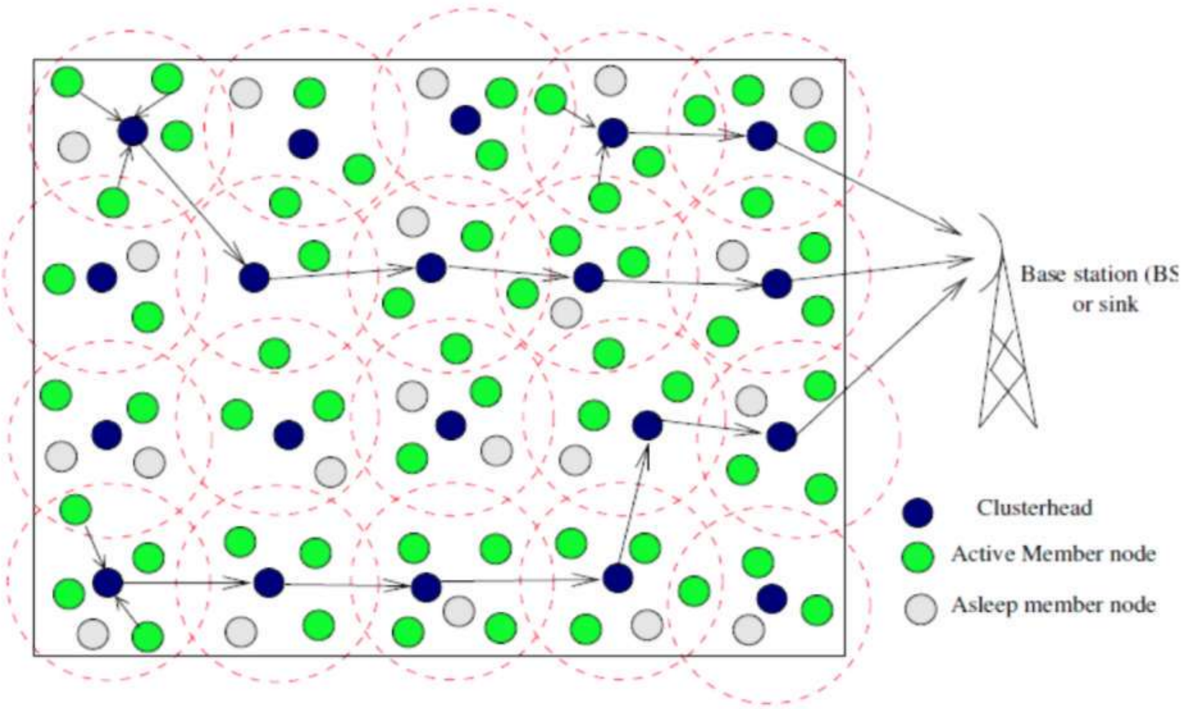


Figure 3.5 – Cluster Based Topology

3.2 Energy Efficiency of Multihop-LEACH Clustering Routing Protocol

In this thesis we select hierarchical routing protocols two types of LEACH, The main differene and very important in these protocol is the energy efficiency, and its only compare this one upward transmission energy dissipation. Path of data transmission from nodes to the base station cross over one or more cluster-head, so will be single or multiple hops respectively.LEACH reduce energy dissipation approximately 7x or 8x time more than direct communications due to the role of cluster-head[41].The efficiency of energy could be summarize to:

- As we mentioned in previous chapter when we gave a full description of LEACH where development focus on saving the energy by make the nearest cluster-head to the sink transmit the data to the it where each node takes its own role to be cluster-head by collect, aggregate and processing the data then send it to the base station. Here in Multi-hop LEACH this scenario is little difference where the data send between cluster-head exclusively, and that may take single or multiple hops according to the distancebeween these nodes and base station, closest cluster-head to the base-station will send the whole data to the sink. This is very useful when the deployed zone is large. Figure (3-6) shows the path of send the data from the cluster-head to another according to their distance from the sink(base-station);
- One other very important characteristic is the energy efficiency, in multi-hop LEACH can be more precise with linear network model. Figure (3-7) shows a diagram for network linearity transmission.

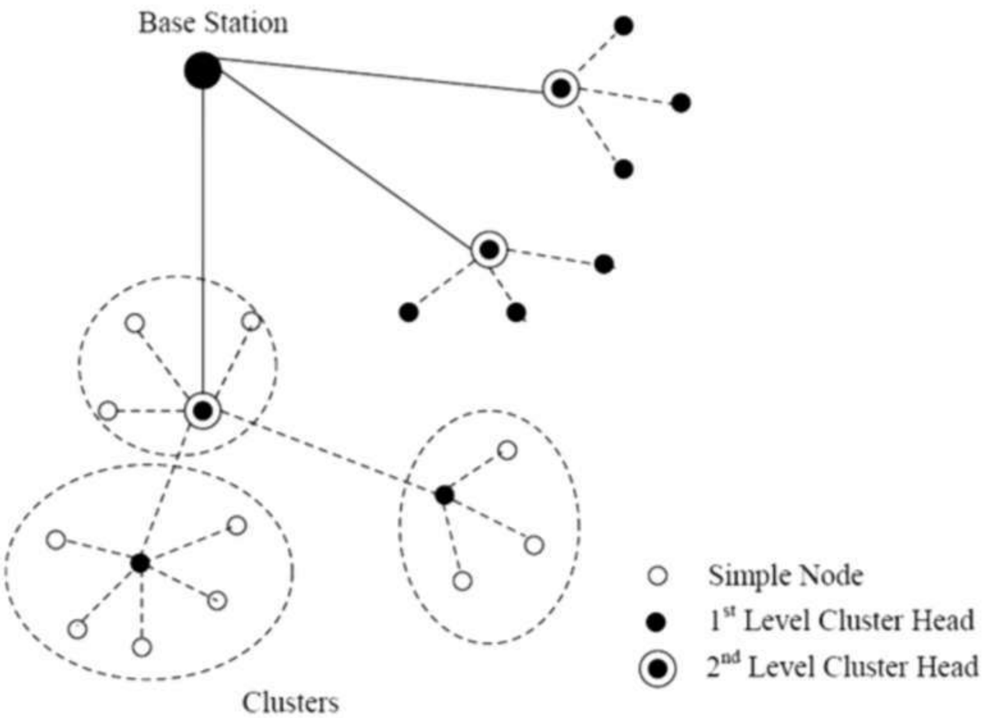


Figure 3.6.– Multi-Path in MH-LEACH

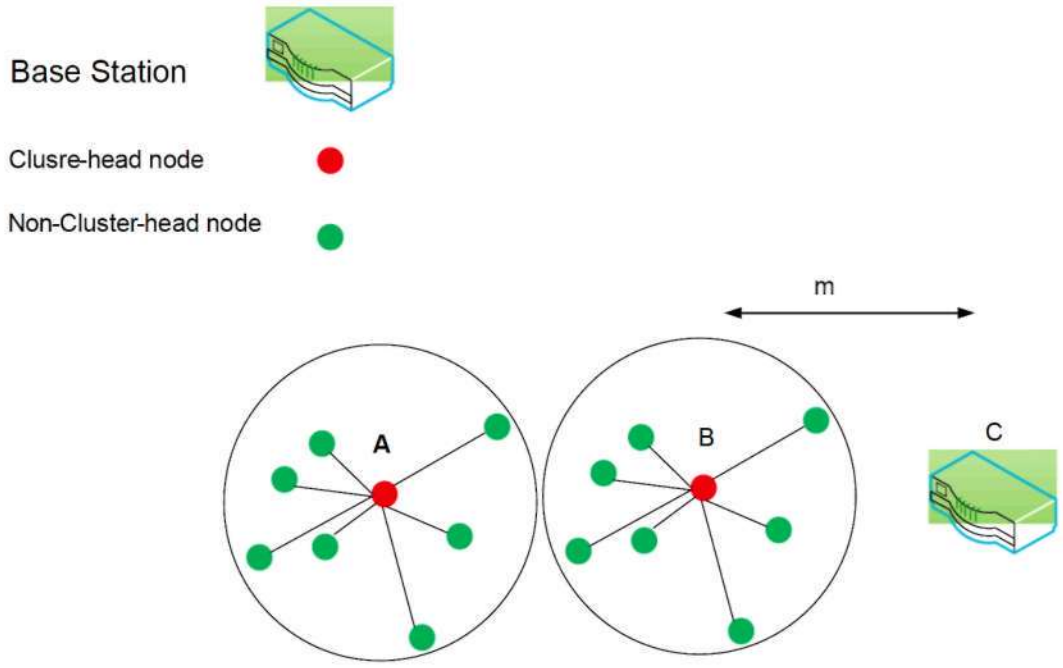


Figure 3.7 – Linear Network Model

Figure above shows two points A and B represents two cluster heads for this simple network, C represent the base-station (sink), m is the distance between BS and CHanssuppose tobe uniform. And both of them need send data to the base-station, in order to calculate the cost of transmitted energy. The equation below will be used:

$$E_{dir} = E_{eleTX} \times L_A + \varepsilon_{amp} \times L_A \times 2m^2 + E_{eleTX} \times L_B + \varepsilon_{amp} \times L_B \times m^2 \tag{3-1}$$

EdirAB is the total cost of energy A and B.

LA collected data by the cluster-head A.

LB collected data by the cluster-head B.

m is the distance CHs and the sink. This occur when each CH will send its aggregated data to the base-station individually.so this equation for LEACH.

In similar way we can calculate the cost of total transmitting energy in case of multi-hop communication. Go back to the same previous diagram if the data need to transmit from A( first cluster-head) to C(base-station), the cluster-head B will take the role of mediator between A and C. accordingly we can reformulate the equation 3-1 to become as below:

$$E_{Multi-hop} = E_{eleTX} \times L_A + \varepsilon_{amp} \times L_A \times m^2 + E_{eleRX} \times L_A + E_{eleTX} \times (L_B + L_A) + \varepsilon_{amp} \times (L_B + L_A) \times m^2 \tag{3-2}$$

the right side of this equation represent the cost of total energy in case of multi-hop communications of Multi-hop LEACH protocol.

Multi-hop LEACH is very important and necessary only with large zone for two reasons:

- Closer cluster-head to the sink has more data burden than other cluster-heads;
- Farthestcluster-head to the base-station also has benefitswhere increase the network lifetime by transmit at small distances.

Other protocols are effective more better if the communication was a single-hop between cluster-head and base-station.

## 3.3 Implemenation and Simulation Results of MH-LEACH protocol

Table 3.1– Simulation and implementation parameters

| Paremeters | Value |
|---|---|
| No of. Nodes | 100 |
| Network size | 200 m x 200 m |
| Base station location | ( 100 , 250 ) |
| Radio propagation speed | 3x 10^8 m/s |
| Processing delay | 50 $\mu s$ |
| Initial Energy | 1 J |
| P (probability to be cluster head) | 0.05 |
| Radio speed | 1 Mbps |
| Data size | 4096 bytes |

---

Algorithm MH-LEACH protocol by Matlab_R2016a

---

```
close all;
clc;
clear;
con=0;
xm = 200;ym = 200;
sink.x =0.5 * xm;
sink.y = ym + 50;
n =100;
p=0.05;
% Energy Model
Eo = 1;
% Eelec=Etx=Erx
ETX1=0.001;
ERX1=0.001;
ETX2=0.0001;
ERX2=0.0001;
% Transmit Amplifier types  Efs,Emp
% Data Aggregation Energy
EDA=5*0.000000001;
INFINITY = 999999999999999;
% Maximum number of rounds
rmax=20;
dead=0;
% END OF PARAMETERS %
figure(1);
for i=1:1:n
S(i).xd=rand(1,1)*xm;
XR(i)=S(i).xd;
S(i).yd=rand(1,1)*ym;
YR(i)=S(i).yd;
% initially there are no cluster heads only nodes
S(i).type=0;
S(i).E=Eo;
plot(S(i).xd,S(i).yd,'o');
hold on;
end
for i=1:1:n
for j=1:1:n
distance(i,j)=((S(i).xd-(S(j).xd))^2 + (S(i).yd-(S(j).yd) )^2 )^(1\2);
end
end
R=((xm*ym)/(5*pi))^(1\2);
L=75;
S(n+1).xd=sink.x;
S(n+1).yd=sink.y;
plot(S(n+1).xd,S(n+1).yd,'X','LineWidth',2,'MarkerSize',20);
for r=1:1:45
ss=rem((r+3),4)+1;
if rem(r-1,4)==0
```

```
figure;
end
E=0;
for i=1:1:n
E=E+S(i).E;
subplot(2,2,ss),plot (S(i).xd,S(i).yd,'o');
hold on;
subplot(2,2,ss), plot (S(n+1).xd,S(n+1).yd,'X','LineWidth',2,'MarkerSize',20);
if S(i).type==1
S(i).type=0;
end
 end
 for i=1:1:n
% checking if there is a dead node
if (S(i).E<=0)
subplot(2,2,ss),plot(S(i).xd,S(i).yd,'b*');
hold on;
if S(i).type==0
dead=dead+1;
S(i).type=2;
end
end
end
if (n-dead<=10)
break;
 end
countCHs=1;
 cluster=1;
for k=1:1:10
for i=1:1:n
c(i)=rand;
if(S(i).E*n>=E && S(i).type ==0)
%Election of Cluster Heads
if( c(i) <= (p/(1-p*mod(r,round(1/p)))))
countCHs = countCHs+1;
S(i).type = 1;
C(cluster).type=S(i).type;
C(cluster).xd = S(i).xd;
C(cluster).yd = S(i).yd;
C(cluster).id = i;
C(cluster).E=S(i).E;
dis(cluster) = sqrt( (S(n+1).xd-S(i).xd)^2 + (S(n+1).yd-S(i).yd)^2 );
cluster=cluster+1;
subplot(2,2,ss), plot(S(i).xd,S(i).yd,'r*');
X=[S(i).xd,S(n+1).xd]; Y=[S(i).yd,S(n+1).yd];
for j=1:1:n
        if distance(i,j)<=R && j~=i && S(j).type==0
        S(j).type=3;
        end
```

```
end
if countCHs==11
con=1;
break;
end
end
end
end
if con==1
con=0;
break;
end
end
for i=1:1:n
if S(i).type ==3
S(i).type =0;
end
min_dis=40000;
if S(i).type ==0
for c=1:1:cluster -1 %cluster - 1
temp =sqrt( (S(i).xd - C(c).xd)^2 + (S(i).yd - C(c).yd)^2 ) ;
if ( temp < min_dis )
min_dis = temp;
j=c;
end
end
if min_dis<L
S(i).E = S(i).E - ETX1 * min_dis- ERX1 * min_dis-ETX2 * min_dis;
C(j).E = C(j).E - ETX1 * min_dis- ERX1 * min_dis-ERX2 * min_dis;
S(C(j).id).E=C(j).E;
X=[S(i).xd,C(j).xd]; Y=[S(i).yd,C(j).yd];
subplot(2,2,ss),plot(X,Y);
hold on;
end
end
end
min_dis=40000;
for i=1:1:cluster -1
if dis(i)<min_dis
min_dis=dis(i);
c=i;
end
end
X=[S(n+1).xd,C(c).xd]; Y=[S(n+1).yd,C(c).yd];
subplot(2,2,ss), plot(X,Y,'r-');
for i=1:1:cluster -1
if i~=c && abs(C(i).yd-C(c).yd)<=50 && dis(i)<distance(C(i).id,C(c).id)
X=[S(n+1).xd,C(i).xd]; Y=[S(n+1).yd,C(i).yd];
subplot(2,2,ss), plot(X,Y,'r-');
end
 end
```

```
for i=1:1:cluster -1
for j=1:1:cluster -1
if abs(C(i).xd-C(j).xd)<=70 && abs(C(i).yd-C(j).yd)<=100 %& distance(C(i).id,C(j).id)<2L
X=[C(i).xd,C(j).xd]; Y=[C(i).yd,C(j).yd];
subplot(2,2,ss), plot(X,Y,'g-');
hold on;
end
end
end
for i=1:1:n
if S(i).type ==1
S(i).E=S(i).E - ETX2 *( sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2 ));
end
end
end
```

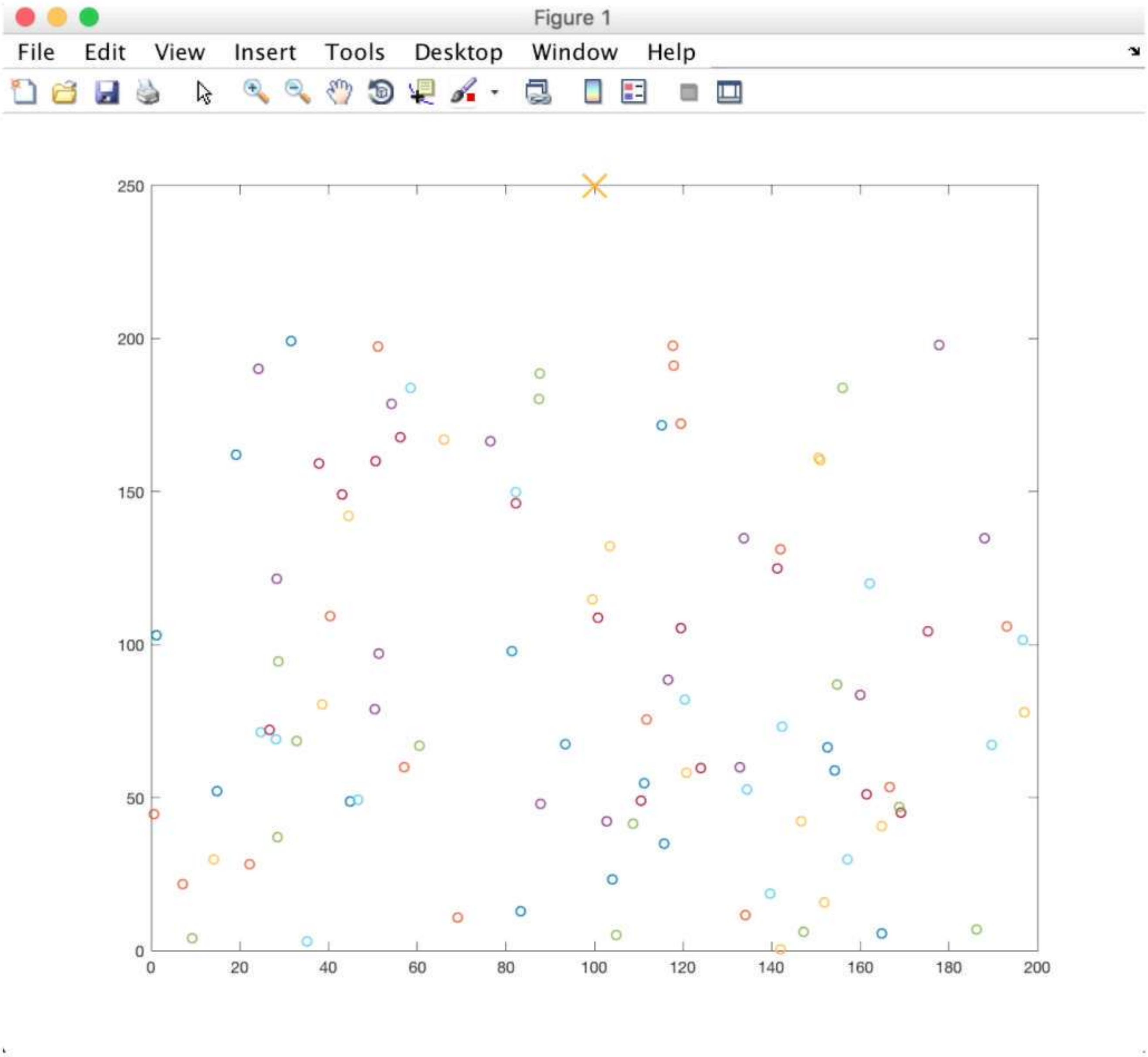
Figure 1
File
Edit
View
Insert
Tools
Desktop
Window
Help
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200

Figure 3.8

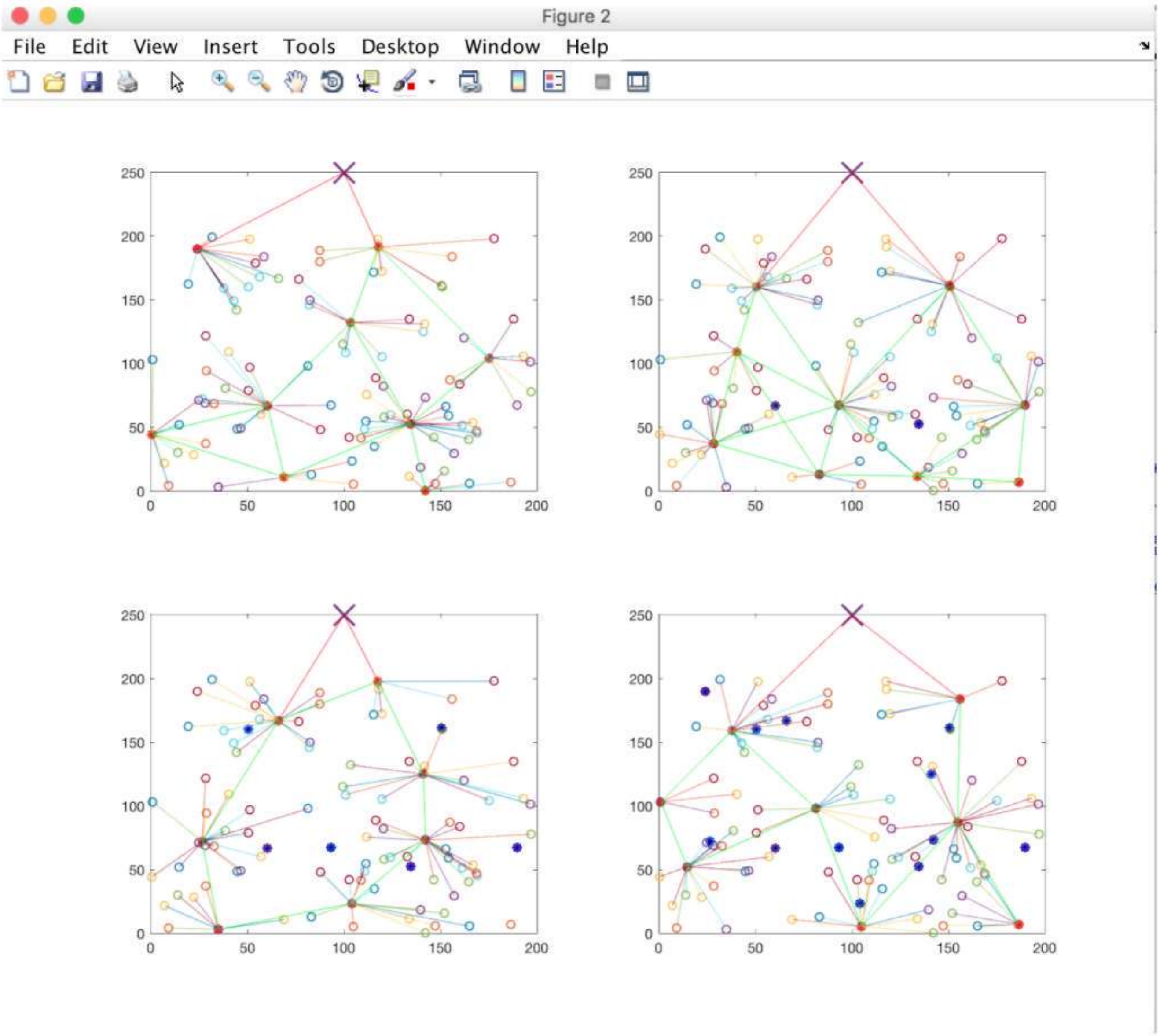


Figure 3.9

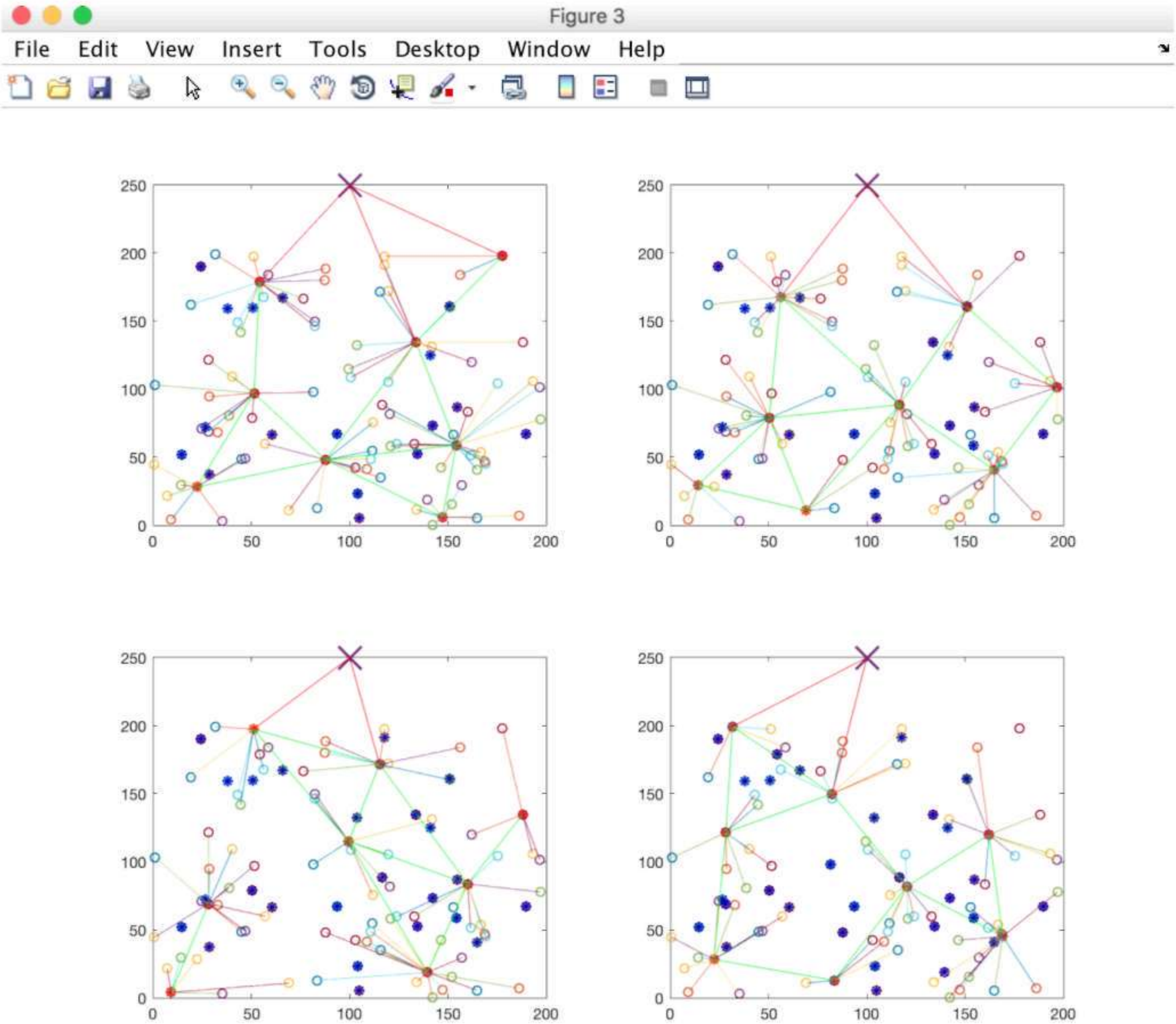
Figure 3
File Edit View Insert Tools Desktop Window Help
250
200
150
100
50
0
0 50 100 150 200

Figure 3.10

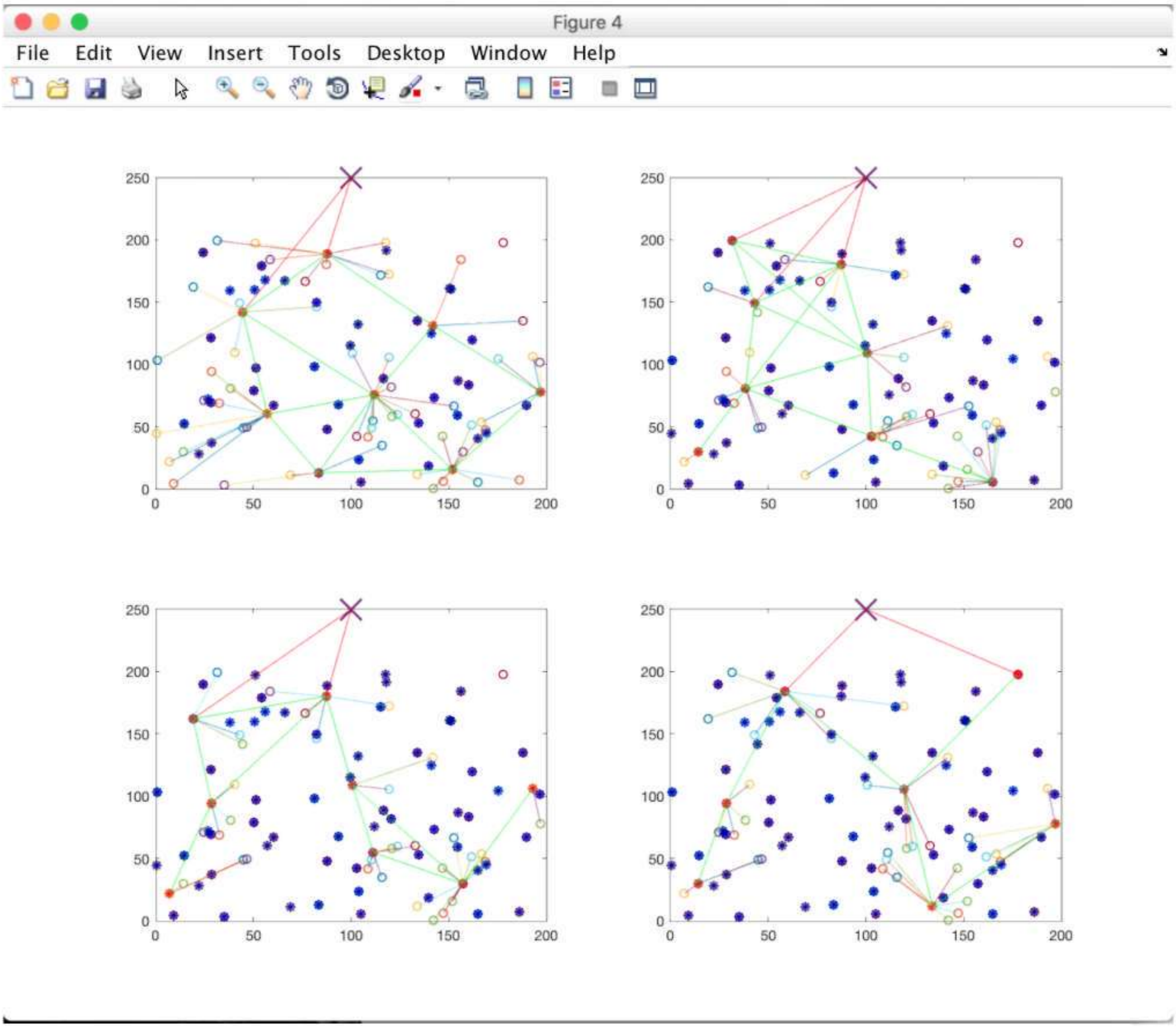


Figure 3. 11

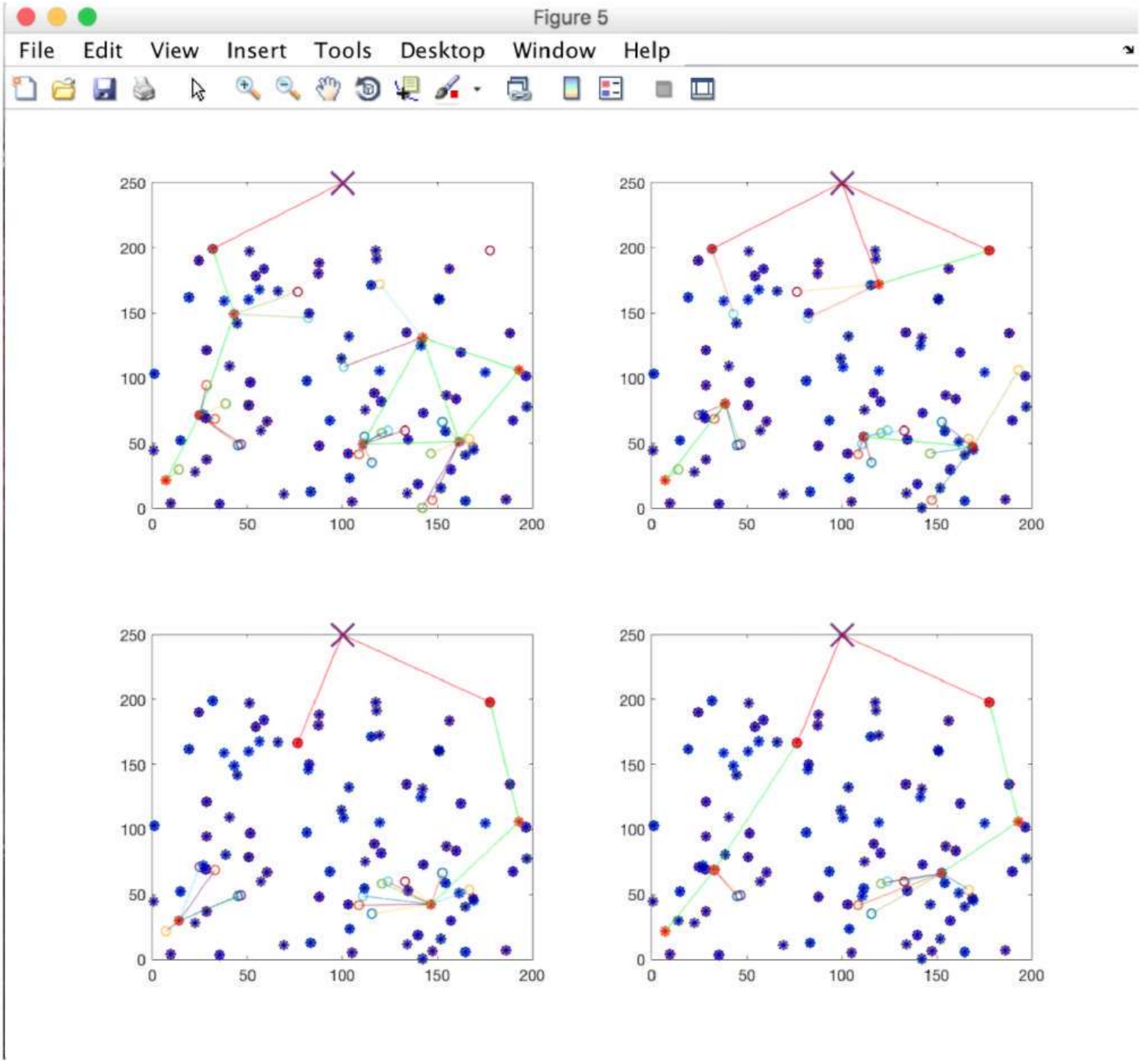


Figure 3.12

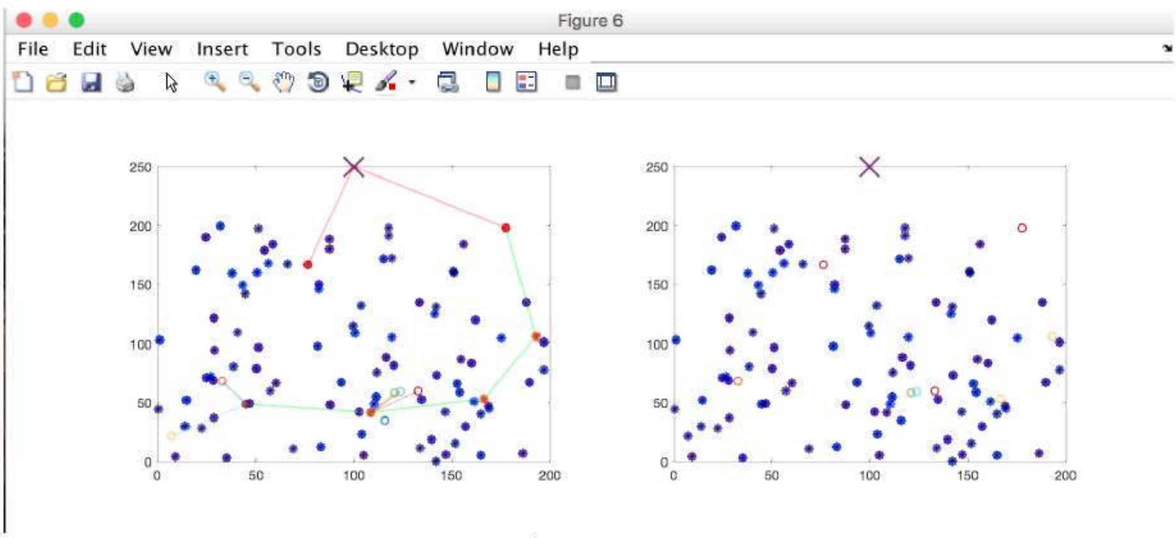


Figure 3.13

## 4 Comparison of LEACH and its modified routing protocols inWSNs

Comparison of LEACH and its modified routing protocols inWSNs Preoccupied researchers for many years, Each one of them has advantages, and characteristics such like, choicing the cluster-heads, number of clusters, forming the clusters, data packets, processing of data, broadcasting and transmitting the data, nodes initial energy levels, so we schedule them as shown below:

| Item or parameter | LEACH | Multi-hop LEACH |
|---|---|---|
| Class | Hierarchical | Hierarchical |
| Mobility of network sensor | Designed for fixed nodes | Designed for fixed nodes |
| expansion | Small zone | Moderated or large zones |
| Organization | Self-organized | Self-organized |
| Rotation of CH | Rotated between nodes | Not –rotated |
| No. of Hops | Single | Multiple |
| Cluster distribution | Each node will take the role of being cluster-head once time per round | CHs Self-elected in clustering algorithm per round |
| Data aggregation | CHs perform it | CHs perform it also |
| propinquity | Homogeneous | Homogeneous |
| BS location | in region centre | at the region edge or out the area |
| Scalability level | Limited | Very Good |
| Resourcesawareness | Good | Very Good |
| Energy Efficiency | High | Very High |
| Cost | Econimc | More expensive |
| Energy consumption between CH & Sink | Limited | More |

# CONCLUSIONS AND FUTURE WORK

In our thesis we discussed LEACH, Multi-hop LEACH for WSNs, the first main goal of our thesis is to develop LEACH, and make it more economic by rotating the role of being cluster-head between the node in each round, that will make the energy consumption less where being cluster-head need to aggregate, collect, processing, and send the data to the base-station. So this role will be evenly distributed between nodes, so that will prolong the network lifetime where the node die at the same time approximately, and make it more economic, but as we mentioned before this is appropriate for average zone, while the second type Multi-Hop LEACH is used in large area, and the sent data packet is larger, and the location of sink is out of deployed area. Noteworthy study and implementation has been done in these two different cluster-based routing protocols where the usage, cost of deployment characteristics, application of these two types are different although they belong to the same family of hierarchical structure protocols, for example using LEACH protocol in medical applications network need to focus on increasing the quality of all design parameters, loss of information will be not acceptable at all, New Bluetooth technique could be used to support using voice and streaming videos to asynchronous data transfers. Finally, it will be important to develop secure communication for wireless microsensor networks. End-users need to be able to ensure unauthorized users cannot access the data from the sensor Networks. Furthermore, end-users need to be able to authenticate the data.

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