Performance Analysis of Routing Protocols in Wireless Sensor Networks

By

Kyaw Min Htet

13507

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering

In Partial Fulfillment of the Requirements

For the Degree

Bachelor of Engineering (Hons)

(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

SUPERVISOR: :Dr.Azrina Binti Abd Aziz

CERTIFICATION OF APPROVAL

Performance Analysis of Routing Protocols in Wireless Sensor Networks

by

Kyaw Min Htet

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____

Dr.Azrina Binti Abd Aziz

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

Kyaw Min Htet

Abstract

Wireless Sensor Networks (WSN) are the networks which comprised of multiple sensing units that have the ability of networking wirelessly, monitor the environmental conditions and can perform signal processing. WSNs are limited by energy, storage capability and power consumption. Therefore, it is important to consider these limitations while choosing routing protocols for WSN. The routing protocols can be categorized based on their attributes and network typology. Performance of these routing protocols can be evaluated by the several performance metrics. This evaluation can be analyzed the performance of routing protocols and the optimization can be done using that analysis. In this project, some of the cluster head based routing protocols will be selected and simulate using MATLAB and the simulated results will be analyzed. Firstly, Low Energy Efficient Adaptive Clustering Hierarchy (LEACH) routing protocol is simulated in MATLAB and analyzed the performance. It is one the most popular routing protocols based on cluster-head routing algorithm. Stable Election Protocol (SEP) routing protocol is also simulated using MATLAB in this project and the evaluation of the performance of the protocol will be discussed.

ACKNOWLEDGEMENTS

I take this opportunity to express my deep gratitude and profound regards to my supervisor Dr.Azrina Binti Abd Aziz for her exemplary guidance, monitoring and constant inspiration throughout the project. The blessing, help and guidance given by her time to time shall bring me a long way in the journey of life.

TABLE OF CONTENTS

Figures

Tables

1 Introduction

1.1 Background of Study

Wireless Sensor Network (WSN) is the system which comprised of multiple sensing modules or sensor that can monitor, communicate and process the sensed data to desired location or host. Each sensor is design to monitor the environmental conditions like environmental temperature, surrounding pressures, vibrations and geographical conditions. These sensors are functioning together as a wireless network and send the required information to the main monitoring control unit. [1]

It can be implemented in many applications such as health care monitoring in hospital, area monitoring in oil and gas structures, forest fire detection, water quality monitoring and air pollution monitoring. Modern WSN are now emerging in the area of automation, agriculture and other fields. So, in telecommunications, WSNs are active research area with different challenges and developments.

In the process of routing, the sensed data from the sensor are delivered from the source to the sink via the most efficient path. The main function of the routing protocols is to set up paths between sensor nodes and data sink [2]. By using efficient routing protocols can enhance the efficiency, performance and lifetime of the WSN. Basically routing techniques in WSNs can be categorized into data-centric, hierarchical and location based protocols in term of their network structure. Under each categorized there are different techniques that can be used to achieve the desired performance.

The routing techniques among WSNs are become very challenging in such ways that the techniques are depending on its application and limited resources such as energy. It is also important to maximize the network lifetime and data capacity that can delivered from the source to sink. The project is mainly focusing on analysis of the cluster based routing protocols in WSNs using performance metrics. [3]

1.2 Problem Statement

In the application of WSNs, there are numerous restrictions such as limited power and energy, the processing time and bandwidth of the network. The modification of routing techniques can minimize the hop, energy consumed per packet, error rate and latency. On the other hand, it can be increased reliability, link quality, data capacity and network lifetime.

Routing in WSNs is also influenced by various challenging factors and these factors must be managed to overcome before efficient WSN is established. Some of these factors are node deployment, data delivery model, power consumption, scalability, mobility of network, transmission media and environmental effects. Due to these impacts, designing the routing protocols is very challenging application dependent. [4]

In order to evaluate the performance of routing protocols, there are various metrics have been used to compare them. Because of The lack of common metrics used, it is difficult to achieve an accurate performance and comparison of routing protocols. So, performance analyzing of routing protocols and understanding of their impact will be the main objective of this project. [5]

1.3 Objectives

To observe the fundamentals of routing protocols in WSNs

To understand the performance metrics of the routing protocols

To analyses the performance of routing protocols and simulate in MATLAB

1.4 Scope of Study

The project needs to understand the fundamentals of WSNs and the routing protocols. In order to achieve that knowledge, researching and studying the basis of WSNs and its routing protocols from trusted sources, journals and conference papers has to be. After that, the specific routing protocols in WSNs will review while carrying out the project. By doing that, more understanding can be achieved and that will assist in analyzing the performances and comparison between these routing protocols.

The project will continued analyzing the cluster based routing protocols using the MATLAB. Choosing of particular protocols and implement those into the MATLAB and analyzing the performance using respective metrics will be covered in the project.

2 Literature Review

Wireless Sensor Network (WSN) involved numerous sensors that can identify or monitor environmental condition like temperature, pressure, motion and other important factors. After detecting the required data, each sensor node has the function of delivering that information to the base control station via gateway sensor node.

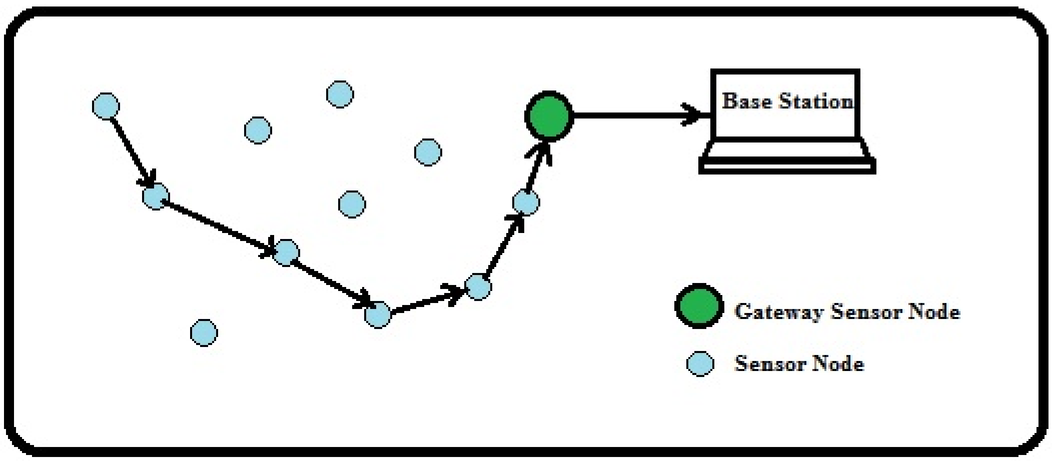


Figure 1: Simple WSN architecture

Routing in the WSNs is the process of delivering data or sensed data from the sensor node to the base station by selecting the best path. In WSNs, the sensor nodes have the capability of wireless communication and data processing. They transform the monitored conditions to the electric signal and deliver to the sink. Sensing nodes usually composed of power unit, processing unit, sensing unit and transceiver unit. Power units may be sustained by power scavenging unit likes solar cells. Processing unit involved storage unit and processor. Sensing Unit composed of sensors and analog to digital converters (ADCs). Transceiver unit are normally connects the node to the network. In some application, the system also included mobilizer unit.

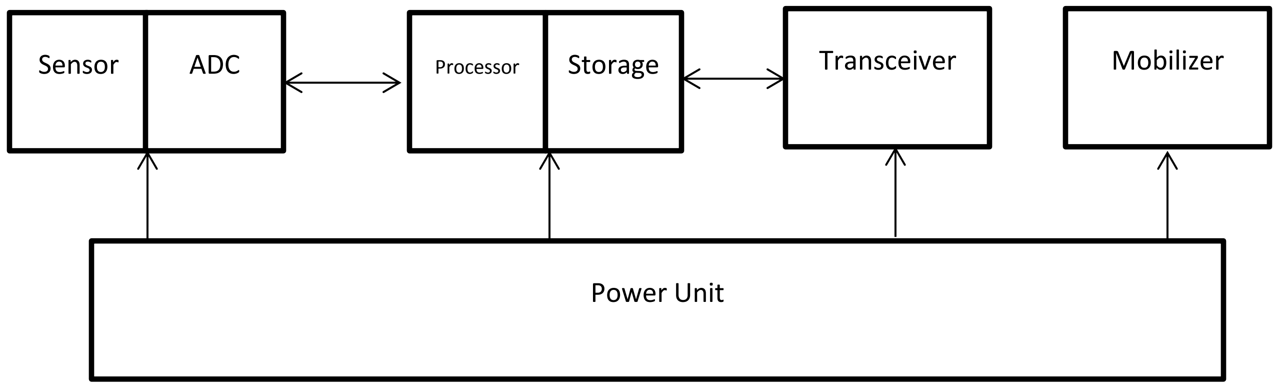


Figure 2 : Components of a sensor node

There are several routing techniques are already proposed for the WSNs. These routing techniques can be categorized into Data Centric, Hierarchical and Location Based, in term of their network structure. Basically, the sink transmits queries to specific regions and the sensors located in that regions response those queries in Data Centric protocols. In Hierarchical routing, high energy nodes are used to process and transmit the information while low energy nodes are performing the sensing that particular area of interest. In Location based routing, nodes know where their geographical region is and to improve the performance of routing to provide new types of services. Besides that, the routing protocols can also be categorized in terms of route selection based and operation based. The summary of these classification are shown below in figure 3. [6]

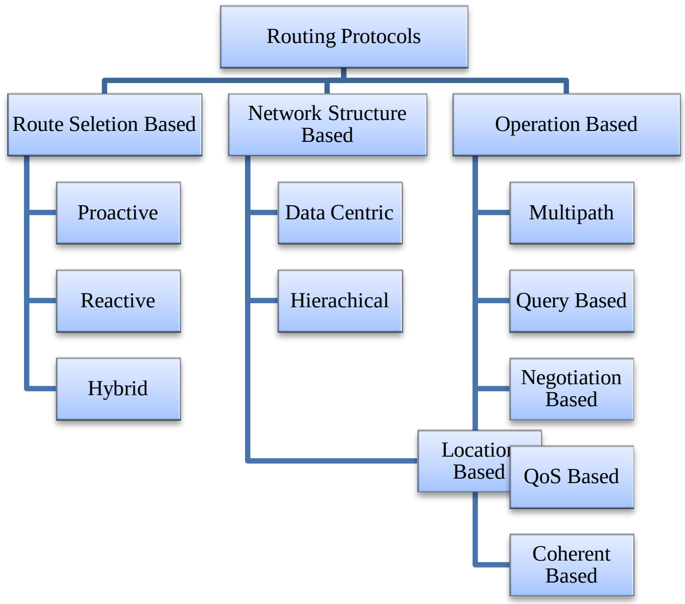


Figure 3 : Summary of Routing Protocols in WSNs

Routing protocols can be evaluated using metric and these metric can identify the effectiveness of a routing protocol. These metrics have a significant effect on comparing one routing protocol with another in such a way that analysis can be done to improve their quality in term of energy, availability and etc. Evaluable metrics can be also categorized into Performance Metrics, General Metrics, Security Metrics, Quality of Service Metrics and Link Quality Metrics. [7]

Clustering is the forming of a group of sensor nodes in a particular area of WSN. The cluster head will be selected in each round of data transmission within that particular area. The cluster head communicated directly with the base station while normal nodes are communicated to the cluster heads, so the energy used by normal nodes could be reduced. Besides, the forming of cluster head will vary form one round to another in order to minimize the energy consumption. The main objective of clustering is to increase the energy efficiency. [8]

For FYP1, Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol is selected to simulation and analyzing. It is the most prior and popular energy-efficient hierarchical clustering routing protocol for WSN under the category of Hierarchical Based Routing Protocols. The main advantages of LEACH routing protocol is it is design to reduce power consumption by introducing the features of choosing cluster-head. The sensor nodes are choosing the cluster-head based on the energy and distance within specific region. And the clustering is rotated among the sensor nodes form one round to another. The cluster head are only nodes to transmit the data to the base station so that the energy consumption is minimized and the lifetime is maximized.[9]

The selection of cluster-head is depending on decision on generating a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \left(\frac{1}{P}\right)\right)}, if\ n \epsilon\ G \\ 0 \qquad , otherwise \end{cases} \qquad (2.1)$$

Where P is suggested percentage of cluster-heads, r equals to current round and G is the set of nodes that have not been cluster-heads in the last 1/P.

The value of energy needs to transmit and receive E_{tx} and E_{rx} of a bit message between two nodes is given by

$$E_{tx} = \begin{cases} E_{elec} * l + \varepsilon_{amp} * l * d^2, if\ d < d_0 \\ E_{elec} * l + \varepsilon_{amp} * l * d^4, if\ d > d_0 \end{cases} \qquad (2.2)$$

$$E_{rx} = E_{elec} * l \qquad (2.3)$$

l is the number of bits in each data message, E_{elec} is the per bit energy dissipation for transmission and reception, d_0 is the threshold transmission distance and $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}}$, ε_{fs} and

ε_{amp} are the amplifier parameters of transmission to free-space and two-ray models respectively.

The energy dissipation in cluster head in one single frame E_{CH} is

$$E_{CH} = l * \frac{N}{k} * (E_{elec} + E_{DA}) + l * \varepsilon_{fs} * d_{toBs}^{4} \qquad (2.4)$$

d_{toBS} is the distance from the cluster-head to the base station, E_{DA} is the energy consumption of one byte in data aggregation.

The energy dissipation of non-cluster-head node is

$$E_{n-CH} = l * E_{elec} + l * \varepsilon_{fs} * d_{toCH}^{2} \qquad (2.5)$$

d_{toCH}^{2} is the distance from the node to the cluster-head.[10]

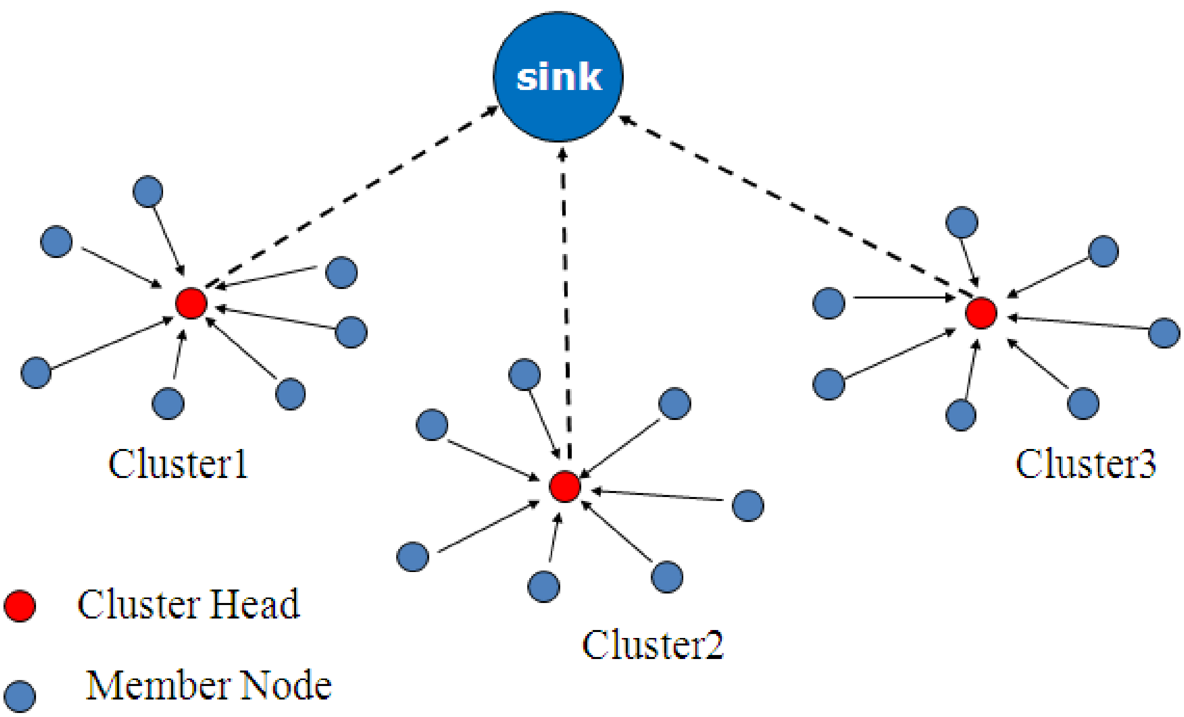


Figure 4 : LEACH routing Protocol

Stable Election Protocol (SEP) is another cluster based and heterogeneous-aware protocol in WSN routing protocols. The main objective of implementing this protocol is to maximize the energy consumption and lifetime of a network. SEP protocol is implementing when there is a need of longer network lifetime which can be crucial for some applications where the feedback from the sensor network must be reliable. SEP protocols included the advanced nodes which are more likely to become the cluster heads than the normal node. The initial energy of these advanced nodes are normally possessed more energy compare to the normal nodes. The initial energy of advances node become $E_0*(1+(\alpha*m))$ where α is the additional energy factor between advanced and normal nodes and *m* is the fraction of advanced nodes. Now some of the nodes possess more initial energy and they would like to operate as advance nodes.This can maximize the stability period (when the first node is death) because the cluster heads are now acquired more energy to operate.[11]

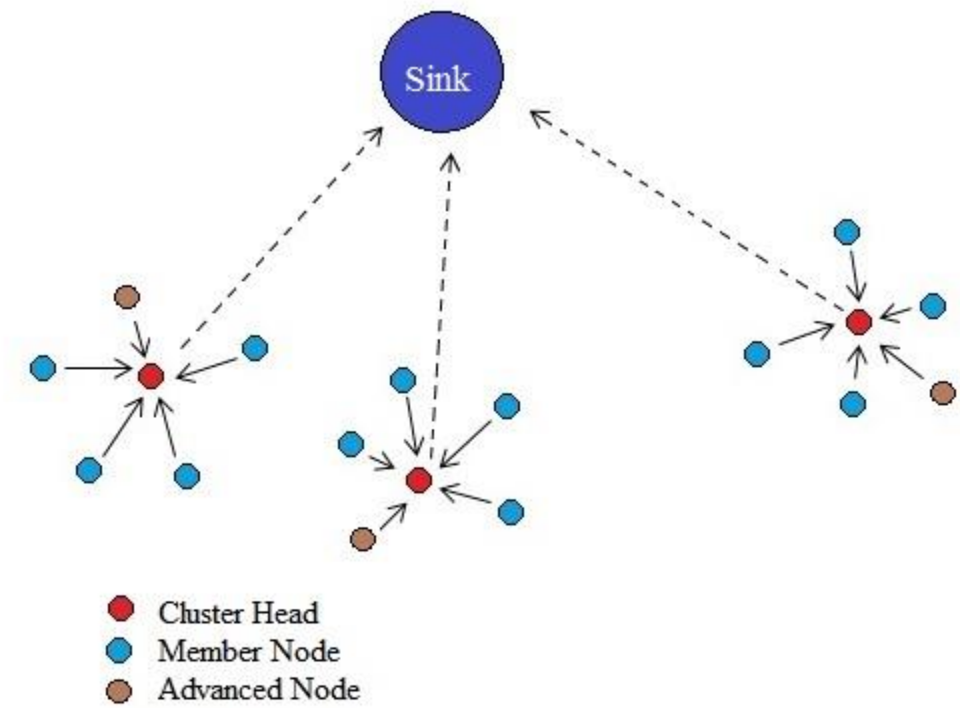


Figure 5: :SEP routing protocol [12]

3 Methodology

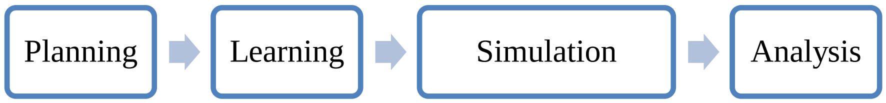


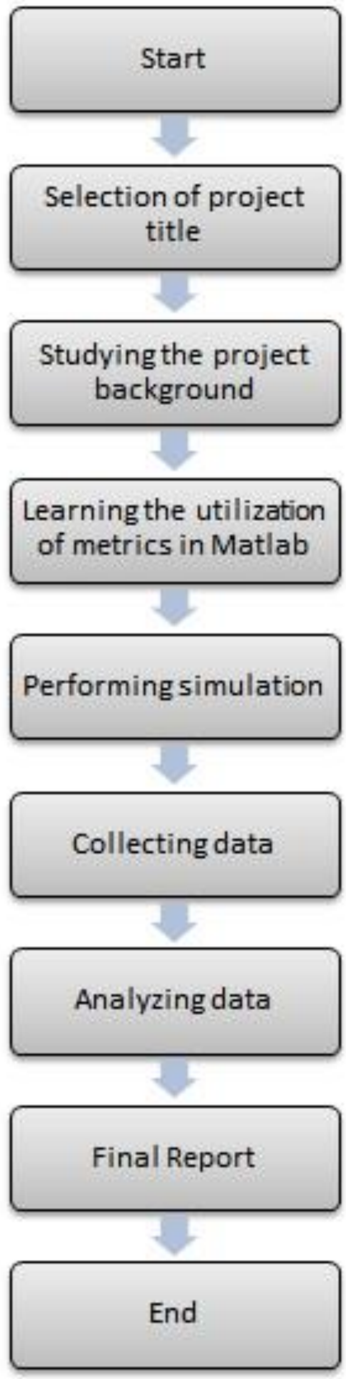
Figure 6 : Methodology of the project

The methodology that is used in this project is learning, implementation and analysis. During the planning stage, I developed scope of study, problem statement and project timeline. Besides that, I also collected the journals, project papers and conference paper that would give knowledge and basic understanding about routing protocols in WSNs.

In the learning stage, the references papers that collected in planning stage are studied and examined. Studying the fundamental of WSNs is the first stage in learning process. At this stage, determination of routing protocols that would like to simulate and analyze by finding out their advantages and usefulness.

Simulation and analysis of routing protocols using MATLAB is important and main methodology in this project. Performance of routing protocols can be evaluated by metrics, and that will be the main part of the project. Such work can be done in the MATLAB simulation and compatibilities of selection of metric will be investigated. Each of the findings will be describe in the final dissertation report. During performing the project I will documented all information concerned with the project.

3.1 Project Activities



3.2 Studying the Project Background

In this stage, studying about the basic and fundamental of WSN has been done. Useful information from journals, project papers, articles and books that can improve the understanding of WSN and its routing protocols are collected and documented to achieve a better understanding about the project.

The checking of availability of the MATLAB codes while choosing the specific routing protocols has been done during this stage. The performance metrics that can be used in future simulation are also studied in order to meet with the objective of the project.

3.3 Simulation and Collecting Data

After all the information about selected routing protocols and performance metrics, the simulation can be carried out to identify the performance of these protocols.

The simulation tool that is used in this project is MATLAB tool. There are some other simulators for WSN but for the feasibility of the project, the MATLAB tool is chosen to simulate the selected WSN protocols.

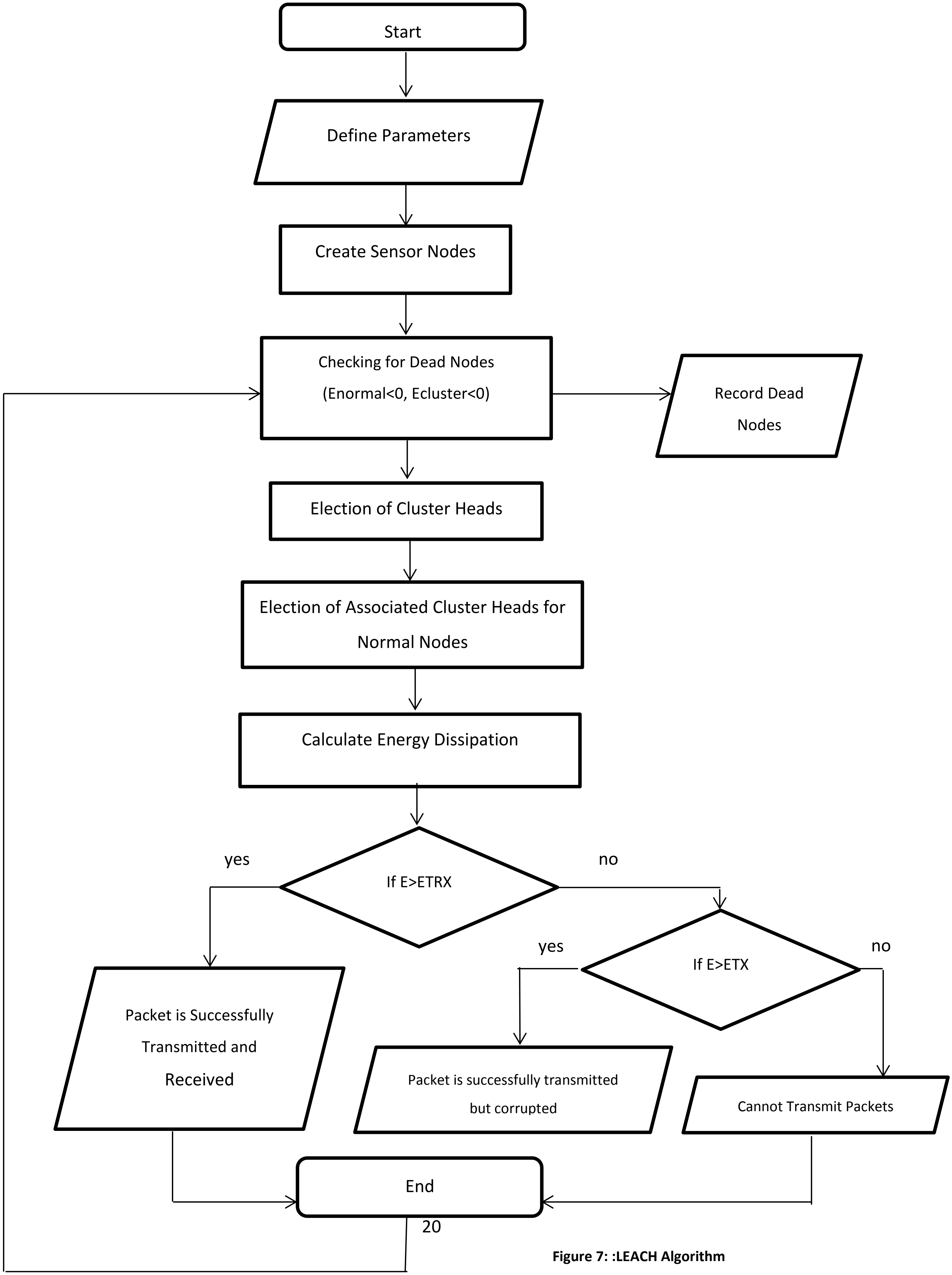


Figure 7: :LEACH Algorithm

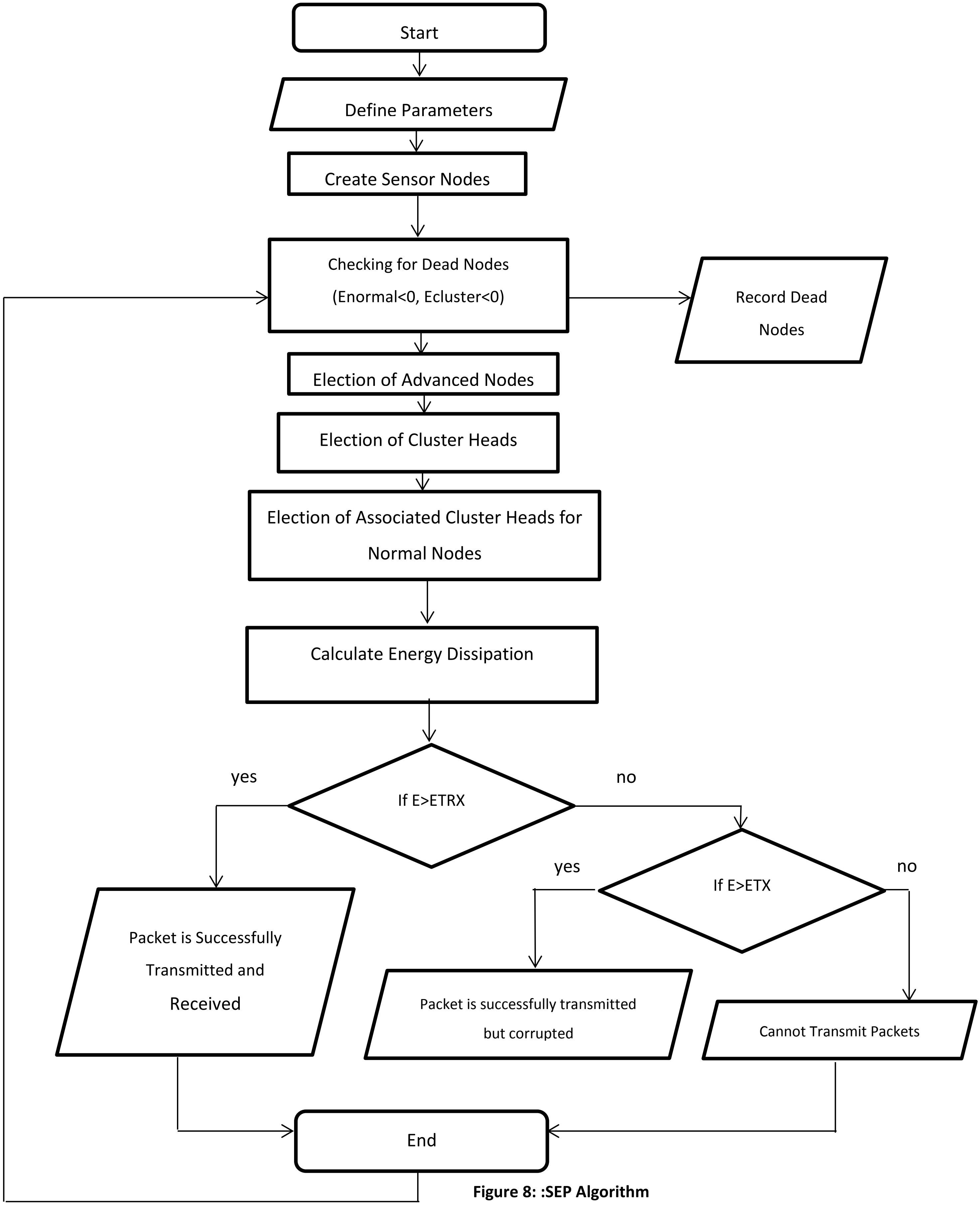


Figure 8: :SEP Algorithm

During the FYP 1, Low Energy Adaptive Clustering Hierarchy (LEACH) is selected to simulate in MATLAB and its performance is measured by performance metrics. It is the most popular routing protocols based on cluster-head routing algorithm. It is design to have a longer network lifetime in such a way that normal nodes are sending the data to their regional cluster heads and only the cluster-head nodes or advance nodes are required to transmit the data to the base station. Selection of cluster-head is depending on the factor of energy and distance. Rotation of choosing the cluster-head for different round is occurred to avoid the energy drainage within cluster-head. So, the total energy consumption by the system is reduced and the system can have a longer lifetime.

Stable Election Protocol (SEP) is another routing protocol that is selected to simulated in MATLAB. It is also the based on cluster-head routing algorithm and heterogeneity. Heterogeneity of the WSN can be defined as the initial energy of the sensor nodes in the field are not the same. Some of the nodes (advanced nodes) have more initial energy compare to the normal nodes in SEP routing protocol. These advanced nodes have more probability of becoming the cluster heads. Because of additional initial energy, these cluster heads in SEP can perform longer duration compare to LEACH.

3.3.1 Simulation Parameters for LEACH and SEP Routing Protocol

To identify the performance of LEACH routing protocol, we evaluated based on the MATLAB simulation. The details of the parameters that were used during simulation are as follow:

Parameters	Values
Quantity of Nodes	100
Network Dimension	100 x 100
Maximum Number of Round	5000
Sink Location	(50,50)
Election Probability of a node to become cluster-head	0.1
Initial Energy	0.5 J
Extra Energy	1 J
Probability of node to become advanced node	0.1
ϵ_{fs} (amplifier parameters of transmission of free-space models)	$1x10^{-8}$ J/bit/m^2
ϵ_{amp} (amplifier parameters of transmission of two-ray models)	$1.3x10^{-15}$ J/bit/m^2
E_{elec} (Energy dissipation for transmission and reception per bit)	$5x10^{-8}$ J/bit
E_{da} (Energy consumption of one byte in data aggregation)	$5x10^{-9}$ J/bit
E_{tx} (Transmission Energy)	$5x10^{-8}$ J/bit
E_{rx} (Receiving Energy)	$5x10^{-8}$ J/bit
E_{trx}(Energy to successfully transmit and receive the packet)	0.0004 J

Table 1 : Simulation Parameters for LEACH and SEP routing protocol

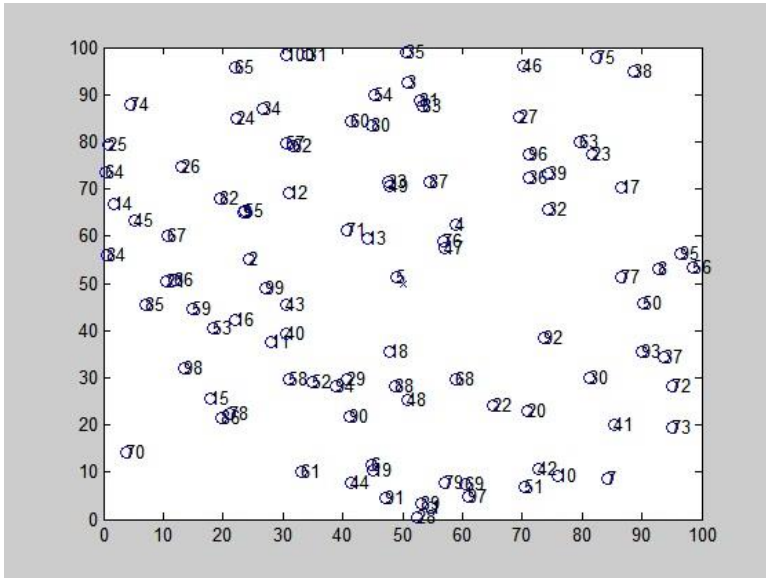


Figure 9 : Node Deployment for LEACH routing protocol with 100 nodes

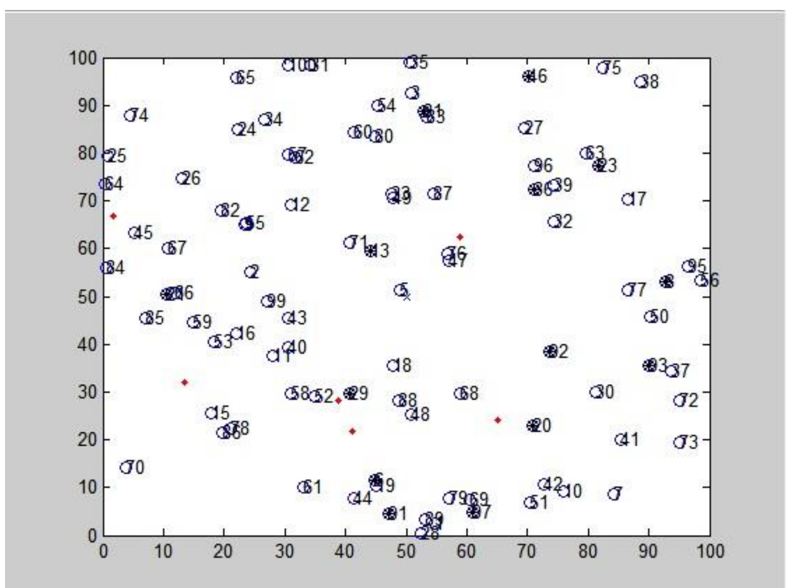


Figure 10 : Normal nodes, cluster-head and dead nodes during LEACH protocol simulation

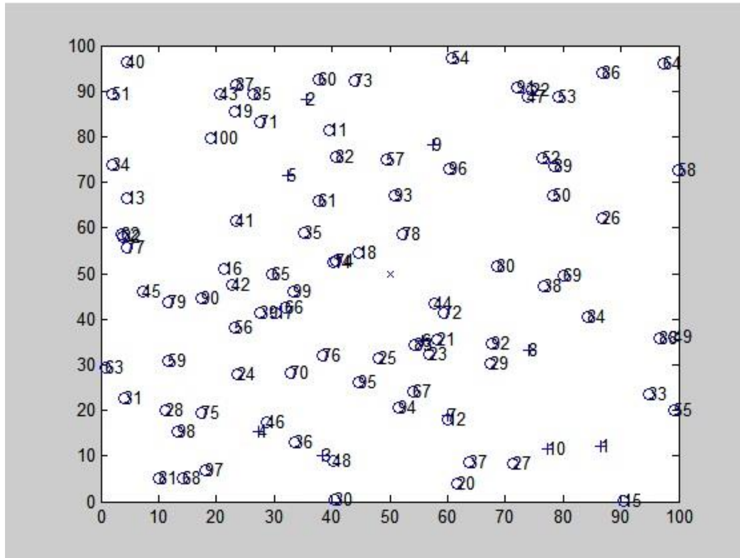


Figure 11: :Node Deployment for SEP routing protocol with 100 nodes

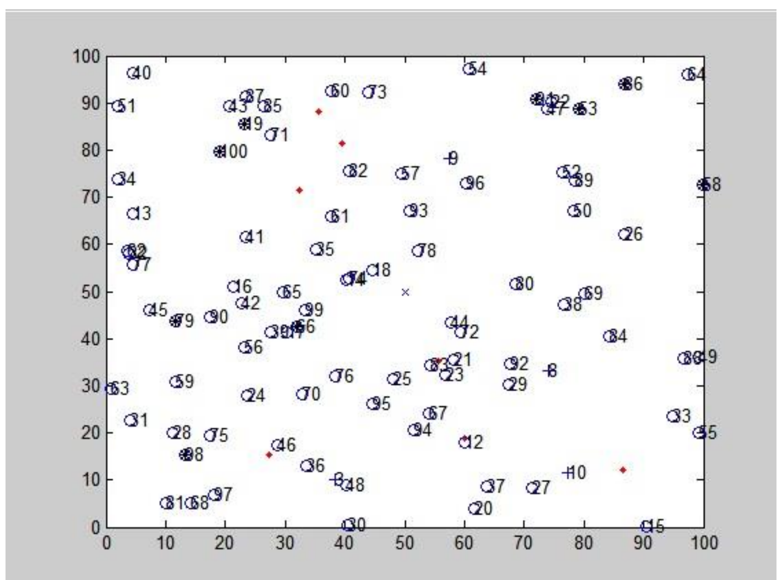


Figure 12: :Normal nodes, advanced nodes, cluster nodes and dead nodes during SEP protocol simulation

The sensor nodes are randomly distributed and the base station has consistent location, during the simulation. All the nodes are homogeneous and energy constrained. Mobility of the sensor nodes are excluded in simulation. Modification of parameters can be made but for the reason of comparing, all the parameters were set with the table 1. The result of the simulation is recorded in the MATLAB.

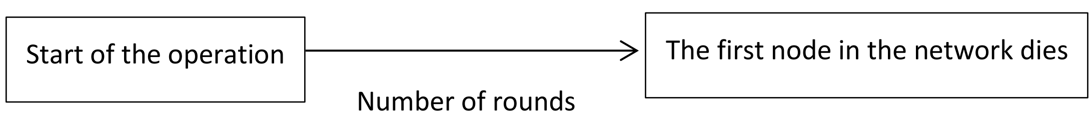
3.3.2 Performance Metrics

1. Network Lifetime

Basically the network lifetime can be defined as the time interval that the wireless sensor network can be operated. To make a reference point, the time interval is by mean of number of round. So the network lifetime is the number round that can be determined as the start of the operation to the round that the last node dies.

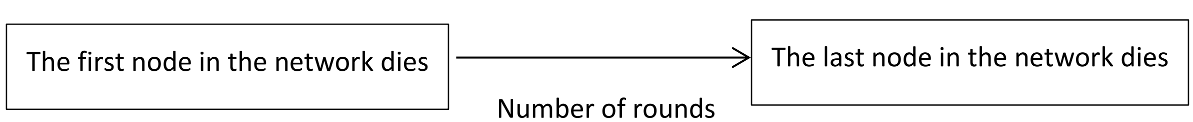
2. Stability Period

The stability period is the number of round start from beginning of operation until the first node of the network die. It can show the stability or reliability period of the network.



3. Instability Period

The instability period can be determined as the number of round from the death of the first node to the death of the last node. It can determine the period of operation of wireless sensor network that cannot be reliable.



4. Average Energy Dissipation

Average Energy Dissipation can indicate the amount of energy is dissipated along the network operation. For the energy limited application, this could show the energy efficiency of the particular protocols.[13]

$$\text{Average Energy Dissipated by Normal Nodes} = \frac{\text{Total Energy Dissipated by Normal Nodes}}{\text{Total Number of Normal Nodes}} \quad (3.1)$$

$$\text{Average Energy Dissipated by Cluster Heads} = \frac{\text{Total Energy Dissipated by Cluster Heads}}{\text{Total Number of Cluster Heads}} \quad (3.2)$$

5. Packet Loss Rate

Packet Loss Rate can be determined the rate of successful message delivered and it is expressed in term of data packets. It is the ratio of the data packets that has loss in the system over the data packets that has transmitted.

$$\text{Packet Loss Rate} = \frac{\text{Number of Packet Loss}}{\text{Number of Packet Transmitted}} \quad (3.3)$$

3.3.3Assumptions

In this project, routing protocols of WSNs are implemented in MATLAB simulation software. The base station of the WSNs has no mobility as well as the sensor nodes. There will be no distraction form the external environment and the system is isolated. The effect of Adaptive White Gaussian Noise (AWGN), multipath components, intersymbol interference (ISI) is ignored so that all transmitted packets are delivered when transmitting nodes and receiving nodes have enough energy.

3.4 Key Milestones and Gantt Chart

No.	Project activities	week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Studying previous work	■													
2	Modifying the previous routing protocols' Code	■	■												
3	Research on another routing protocols in WSNs			■	■	■									
4	Executing the routing protocols in MATLAB						■	■	■	■	■	■	■	■	
5	Preparing Progress Report							■	■						
6	Performing simulation							■	■	■	■	■	■		
7	Data analysis										■	■	■	■	
8	Preparing final report													■	■

Figure 13 : Key Milestones and Gantt Chart

3.5 Software Required

To performing the project, the following software are needed

- MATLAB
- Microsoft Office
- Microsoft Excel

4 Results and Discussion

The simulated results for routing protocols are analyzed based on the performance metrics .The first performance metric is the network lifetime. The comparison the network lifetime of the routing protocols is illustrated in figure below to see which protocols has better network lifetime of operation.

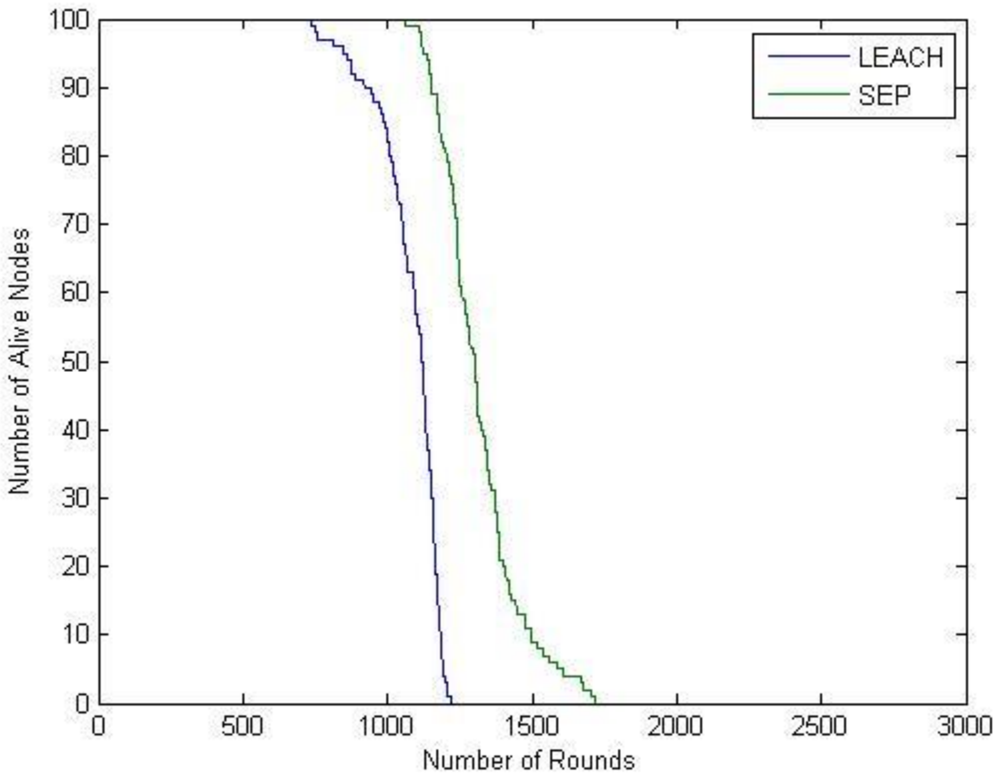


Figure 14: : Network lifetime

Based on the result, LEACH routing protocol has the network lifetime of 1223 rounds and SEP routing protocol has the network lifetime of 1722 rounds. So, the SEP routing protocol has a longer network lifetime compare to the LEACH routing protocol.

Besides, the stability period of the LEACH protocol is up to round number 736. It has a short stability period compared to the SEP protocol which has stability period of 1065 rounds. Instability period of the LEACH is round number 736 to 1223 while SEP has round number 1065 to 1722. So the SEP routing protocol is more reliable than the LEACH protocol because it has the better stability period. In term of instability period these two routing protocols has no significance difference.

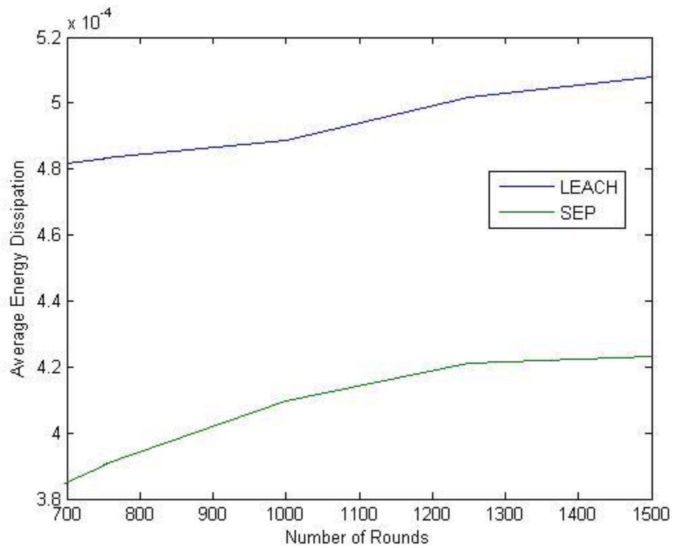


Figure 15: :Average Energy Dissipation by Normal Nodes

In term of average energy dissipation by normal nodes, LEACH protocol has more energy dissipation than the SEP protocol. For the normal nodes SEP is more energy efficient than the LEACH.

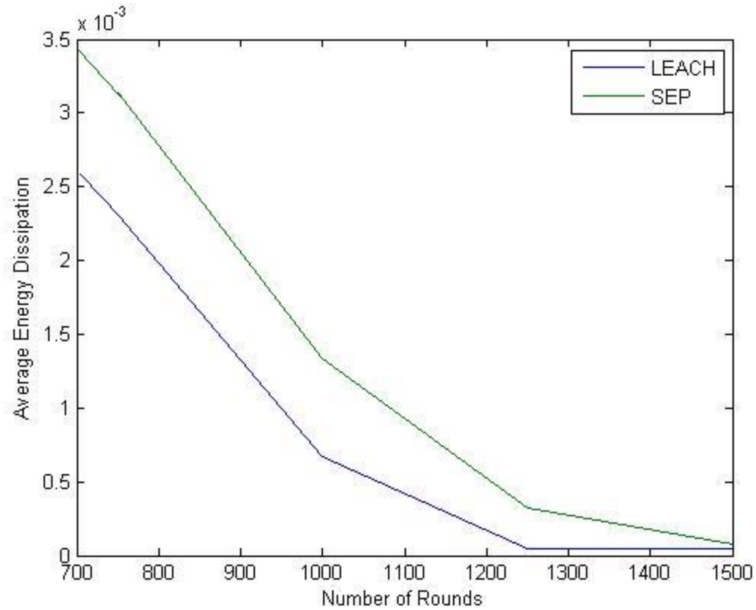


Figure 16: : Average Energy Dissipation by Cluster Heads

For cluster heads, the LEACH protocol has better energy efficiency than the SEP protocol. SEP protocol included advanced nodes which has additional energy. When this advanced nodes becomes the cluster heads it can dissipate more energy than the cluster heads of LEACH protocol.

In term of packet loss rate, the LEACH protocol has 0.0007 (0.07%) and SEP protocol has 0.00077 (0.077%). Packet loss rate indicated the network performance in term of packet lost related with the amount of packet transmitted. Almost equivalent performance is showed for LEACH and SEP protocols.

5 Conclusion

Wireless Sensor Network (WSN) is the system which comprised of multiple sensing modules or sensor that can monitor, communicate and process the sensed data to desired location or host. WSNs have the application on environmental monitoring, vibrations and geographical conditions. In WSNs the process of sending the required information from the source to the sink, gateway sensor and base station is call the routing. Routing protocols in WSNs can be categorized by their network typology, route selection and their operations. Under each categories there are several routing protocols based on different techniques. There are several metrics to evaluate the performance of these routing protocols and selecting of these metrics can vary the performances. The simulation can be run in the MATLAB for analyzing the performance of these routing protocols. The methodology for carrying out the project is planning, learning, simulation and analyzing. The basic and fundamental about the WSN and routing protocols are studied before executing the protocol to simulation platform. Simulation and analyzing the performance of these routing protocols with performance metrics using the aid of MATLAB will be the core part of the project. At this time, the LEACH routing protocol and SEP routing protocol is implemented in MATLAB and simulated. The performance of the protocol is determined by the lifetime of the network, stability period, instability period ,average energy consumption and packet loss rate.

6 References

[1] Laiali Almazaydeh, Eman Abdelfattah, Manal Al- Bzoor, and Amer Al- Rahayfeh, "Performance Evaluation of Routing Protocols in Wireless Sensor Network", University of Bridgeport, Bridgeport,USA, April 2010.

[2] Kazem Sohraby, Daniel Minoli, Taieb Znati, "Wireless Sensor Networks: Technology, Protocols and Application", 2007.

[3][11] [12] Georgios Smaragdakis, Ibrahim Matta, Azer Bestavros, " SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks, Coumputer Science Deparment, Boston University.

[4] Mohammad Kafee Uddin and Aloukik Mishra, "Routing in a Wireless Sensor Network, ISM Dhanbad", December 2012.

[5] Neha Rathi, Jyoti Saraswat and Partha Pratim Bhattacharya," A Review on Routing Protocols for Application in Wireless Sensor Network", Deemed University, India, Spetember 2012.

[6] Jamal N. Al-Karaki and Ahmed E.Kamal," Routing Techniques in Wireless Sensor Network: A Survey", Iowa State University, Ames Iowa,

[7] Darpan Dekivadiya and Vivek Vadharia, "Performance Analysis of Routing Protocols of Wireless Sensor Network", Nirma University, India, November 2012.

[8] L.V. Bijuraj,"Clustering and its Applications", Proceedings of National Conference on New Horizons in IT.

[9][10]Ningbo Wang, Hao Zhu, "An Energy Efficient Algrithm Based on LEACH Protocol", Internaitonal Conference on Computer Science and Electronics Engineering, 2012.

[13] Said Ben Alla, Abdellah Ezzati, Ahmed Mohsen, "Hierarchical Adaptive Balanced Routing Protcol for Energy Efficiency in Hetrogeneous Wireless Sensor Networks, "Science and Technical Faculty Hassan, University Settat, Moroco

7 APPENDIX

APPENDIX A

MATLAB CODE FOR LEACH ROUTING PROTOCOL

```

clear;
%%%%%%%%%%%%%%%%%%%%%%%%% PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%%%

%Field Dimensions - x and y maximum (in meters)
xm=100;
ym=100;
%x and y Coordinates of the Sink
sink.x=0.5*xm;
sink.y=0.5*ym;

%Number of Nodes in the field
n=100

%Optimal Election Probability of a node to become cluster head/
p=0.1;
%Energy Model (all values in Joules)
%Initial Energy
Eo=0.5;
%Eelec=Etx=Erx
ETX=50*0.000000001;

ERX=50*0.000000001;
ETRX=0.005;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=0.0013*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;
%maximum number of rounds
rmax=2000
%%%%%%%%%%%%%%%%%%%%%%%%% END OF PARAMETERS %%%%%%%%%%%%%%%%%%%%
```

```
%Computation of do
do=sqrt(Efs/Emp);
%Creation of the random Sensor Network
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;
    S(i).G=0;
    %initially there are no cluster heads only nodes
    S(i).type='N';

    temp_rnd0=i;
    %Random Election of Normal Nodes

        S(i).E=Eo;
        S(i).ENERGY=0;

end
S(n+1).xd=sink.x;
S(n+1).yd=sink.y;
plot(S(n+1).xd,S(n+1).yd,'x');


%First Iteration
figure(1);

%counter for CHs
countCHs=0;
%counter for CHs per round
rcountCHs=0;
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
cluster=1;

countCHs;
rcountCHs=rcountCHs+countCHs;
flag_first_dead=0;
tic
for r=0:1:rmax
    r

  %Operation for epoch
  if(mod(r, round(1/p) )==0)
    for i=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;

%counter for bit transmitted to Bases Station and to Cluster Heads,
packets_TO_BS=0;
packets_TO_CH=0;
pr=0;
pt=0;
%counter for bit transmitted to Bases Station and to Cluster Heads
```

```
PACKETS_TO_CH(r+1)=0;
PACKETS_TO_BS(r+1)=0;
p_r(r+1)=0;
p_t(r+1)=0;

figure(1);

for i=1:1:n
    %checking if there is a dead node
    if (S(i).E<=0)
        plot(S(i).xd,S(i).yd,'red .');
        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,'o');
        text(S(i).xd,S(i).yd,num2str(i));%labeling the sensor nodes
        end

        hold on;
    end
end
plot(S(n+1).xd,S(n+1).yd,'x');

```

```
STATISTICS(r+1).DEAD=dead;
DEAD(r+1)=dead;
DEAD_N(r+1)=dead_n;
DEAD_A(r+1)=dead_a;
Alive_N(r+1)=n-dead;
Round(r+1)=r;
%When the first node dies
if (dead==1)
    if(flag_first_dead==0)
        first_dead=r
        flag_first_dead=1;
    end
end

countCHs=0;
cluster=1;
for i=1:1:n
   if(S(i).E>0)
   temp_rand=rand;
   if ( (S(i).G)<=0)

 %Election of Cluster Heads
 if(temp_rand<= (p/(1-p*mod(r,round(1/p)))))
            countCHs=countCHs+1;
            packets_TO_BS=packets_TO_BS+1;
            PACKETS_TO_BS(r+1)=packets_TO_BS;

            S(i).type='C';
            S(i).G=round(1/p)-1;
            C(cluster).xd=S(i).xd;
            C(cluster).yd=S(i).yd;
            plot(S(i).xd,S(i).yd,'k*');
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
            distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 + (S(i).yd-(S(n+1).yd) )^2 );
            C(cluster).distance=distance;
            C(cluster).id=i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;

            %Calculation of Energy dissipated
            distance;
            if (distance>do)
                S(i).EF=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
                S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
                if(S(i).E>ETX)
                if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end

                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (distance<=do)
                S(i).EF=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
                    S(i).E=S(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance * distance ));
                    if(S(i).E>ETX)
                    if(S(i).E>ETRX)
                        pt=pt+1;
                        pr=pr+1;
                        p_t(r+1)=pt;
                        p_r(r+1)=pr;
                    end
                    if(S(i).E<ETRX)

                        pt=pt+1;

                        p_t(r+1)=pt;

                        end

                    end
                end
                if(S(i).EF<0)
                    S(i).EF=0;
                end
            end

        end
      end
    end

STATISTICS(r+1).CLUSTERHEADS=cluster-1;
CLUSTERHS(r+1)=cluster-1;

%Election of Associated Cluster Head for Normal Nodes
for i=1:1:n
    if ( S(i).type=='N' && S(i).E>0 )
```

Untitled × LEACHERE.m* ×

```
    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-C(c).xd)^2 + (S(i).yd-C(c).yd)^2 ) );
            if ( temp<min_dis )
                min_dis=temp;
                min_dis_cluster=c;
            end
        end

        %Energy dissipated by associated Cluster Head
             min_dis;
             if (min_dis>do)
                 S(i).E=S(i).E- ( ETX*(4000) + Emp*4000*( min_dis * min_dis * min_dis * min_dis));
             S(i).EF= S(i).EF;
             if(S(i).E>ETX)
             if(S(i).E>ETRX)
                     pt=pt+1;
                     pr=pr+1;
                     p_t(r+1)=pt;
                     p_r(r+1)=pr;
                 end
                 if(S(i).E<ETRX)

                     pt=pt+1;

                     p_t(r+1)=pt;

                     end

```

```
                end

            end
            if (min_dis<=do)
                S(i).E=S(i).E- ( ETX*(4000) + Efs*4000*( min_dis * min_dis));
            S(i).EF= S(i).EF;
            if(S(i).E>ETX)
            if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end
                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (S(i).E<0)
                S(i).E=0;

            end
            U(i)= S(i).E;
            R(i)= Eo:Eo:Eo;
           EC(i)= R(i)-U(i);
           TEC=sum(EC);
```

```
            TEC=sum(EC);
            TCHS=sum(CLUSTERHS);

         if(min_dis>0)
           S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ( (ERX + EDA)*4000 );
          PACKETS_TO_CH(r+1)=n-dead-cluster+1;
         end

        S(i).min_dis=min_dis;
        S(i).min_dis_cluster=min_dis_cluster;

   end
  end
end
hold on;

countCHs;
rcountCHs=rcountCHs+countCHs;
end
t=toc
for i=1:1:n

P(i)=[S(i).EF];%double array of energy left in normal node
Energy_Dissipated_By_Normal_Nodes(i)=R(i)-P(i);
end
Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
%TNN=sum(NN);
Total_Energy_Avaliable=sum(R);
Total_Energy_Dissipated_By_Normal_Nodes=sum(Energy_Dissipated_By_Normal_Nodes);
Total_Energy_Dissipated_By_Cluster_Heads=Total_Energy_Avaliable-Total_Energy_Dissipated_By_Normal_Nodes;
Total_Number_of_Cluster_Heads=sum(CLUSTERHS);
Average_Energy_Dissipated_Per_Cluster_Heads=Total_Energy_Dissipated_By_Cluster_Heads/Total_Number_of_Cluster_Heads;
Total_Number_of_Normal_Nodes=sum(Number_of_Normal_Nodes);
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
P(i)=[S(i).EF];%double array of energy left in normal node
Energy_Dissipated_By_Normal_Nodes(i)=R(i)-P(i);
end
Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
%TNN=sum(NN);
Total_Energy_Avaliable=sum(R);
Total_Energy_Dissipated_By_Normal_Nodes=sum(Energy_Dissipated_By_Normal_Nodes);
Total_Energy_Dissipated_By_Cluster_Heads=Total_Energy_Avaliable-Total_Energy_Dissipated_By_Normal_Nodes;
Total_Number_of_Cluster_Heads=sum(CLUSTERHS);
Average_Energy_Dissipated_Per_Cluster_Heads=Total_Energy_Dissipated_By_Cluster_Heads/Total_Number_of_Cluster_Heads;
Total_Number_of_Normal_Nodes=sum(Number_of_Normal_Nodes);
Average_Energy_Dissipated_Per_Normal_Nodes=Total_Energy_Dissipated_By_Normal_Nodes/Total_Number_of_Normal_Nodes;
dead_a;
dead_n;
dead_nodes=dead_a+dead_n;
alive_nodes=n-dead_nodes;
first_node_died=0;


figure(2);

plot (Round,Alive_N,'r')
xlabel('number of rounds')
ylabel('alives nodes')
```

Untitled x LEACHERE.m* x

APPENDIX B

MATLAB CODE FOR SEP ROUTING PROTOCOL

```

clear;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Field Dimensions - x and y maximum (in meters)
xm=100;
ym=100;

%x and y Coordinates of the Sink
sink.x=0.5*xm;
sink.y=0.5*ym;

%Number of Nodes in the field
n=100;

%Optimal Election Probability of a node
%to become cluster head
p=0.1;

%Energy Model (all values in Joules)
%Initial Energy
Eo=0.5;
%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;
ETRX=0.005;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=0.0013*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;
```

```
%Values for Hetereogeneity
%Percentage of nodes than are advanced
m=0.1;
%\alpha
a=1;

%maximum number of rounds
rmax=2000;


%%%%%%%%%%%%%%%%%%%%%%%%%% END OF PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%%

%Computation of do
do=sqrt(Efs/Emp);

%Creation of the random Sensor Network
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;
    S(i).G=0;
    %initially there are no cluster heads only nodes
    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,'o');
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
            hold
        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,'+');
             hold on;
        end
    end

    S(n+1).xd=sink.x;
    S(n+1).yd=sink.y;
    plot(S(n+1).xd,S(n+1).yd,'x');


    %First Iteration
    figure(1);

    %counter for CHs
    countCHs=0;
    %counter for CHs per round
    rcountCHs=0;
    cluster=1;

    countCHs;
    rcountCHs=rcountCHs+countCHs;
    flag_first_dead=0;
    tic
    for r=0:1:rmax
        r

```

Divide value near cursor and evaluate cell (Ctrl+NumPad /)

Untitled | LEACHEREGG.m | SEPerGG.m

File Edit Text Go Cell Tools Debug Desktop Window Help

```
  %Election Probability for Normal Nodes
  pnrm=( p/  (1+a*m) );
  %Election Probability for Advanced Nodes
  padv= ( p*(1+a)/(1+a*m) );

  %Operation for heterogeneous epoch
  if(mod(r, round(1/pnrm) )==0)
    for i=1:1:n
        S(i).G=0;
        S(i).cl=0;
    end
  end

 %Operations for sub-epochs
 if(mod(r, round(1/padv) )==0)
    for i=1:1:n
        if(S(i).ENERGY==1)
            S(i).G=0;
            S(i).cl=0;
        end
    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;
```

```
%counter for bit transmitted to Bases Station and to Cluster Heads
packets_TO_BS=0;
packets_TO_CH=0;
pr=0;
pt=0;
%counter for bit transmitted to Bases Station and to Cluster Heads
%per round
PACKETS_TO_CH(r+1)=0;
PACKETS_TO_BS(r+1)=0;
p_r(r+1)=0;
p_t(r+1)=0;

figure(1);

for i=1:1:n
    %checking if there is a dead node
    if (S(i).E<=0)
        plot(S(i).xd,S(i).yd,'red .');
        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,'o');
        text(S(i).xd,S(i).yd,num2str(i));%labeling the sensor nodes
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
            end
            if (S(i).ENERGY==1)
            plot(S(i).xd,S(i).yd,'+');
            text(S(i).xd,S(i).yd,num2str(i));
            end
            hold on;
        end
end
plot(S(n+1).xd,S(n+1).yd,'x');


STATISTICS(r+1).DEAD=dead;
DEAD(r+1)=dead;
DEAD_N(r+1)=dead_n;
DEAD_A(r+1)=dead_a;
Alive_N(r+1)=n-dead;
Round(r+1)=r;
%When the first node dies
if (dead==1)
    if(flag_first_dead==0)
        first_dead=r
        toc
        flag_first_dead=1;
    end
end

countCHs=0;
cluster=1;
for i=1:1:n
   if(S(i).E>0)
   temp_rand=rand;
   if ( (S(i).G)<=0)
```

```
%Election of Cluster Heads for normal nodes
if( ( S(i).ENERGY==0 && ( temp_rand <= ( pnrm / ( 1 - pnrm * mod(r,round(1/pnrm)) )) ) )  )

            countCHs=countCHs+1;
            packets_TO_BS=packets_TO_BS+1;
            PACKETS_TO_BS(r+1)=packets_TO_BS;

            S(i).type='C';
            S(i).G=100;
            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 );
            C(cluster).distance=distance;
            C(cluster).id=i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;

            %Calculation of Energy dissipated
            distance;
            if (distance>do)
                S(i).EF=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
                S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
           if(S(i).E>ETX)
                if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end
```

```
                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (distance<=do)
                 S(i).EF=S(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance * distance ));
                S(i).E=S(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance * distance ));
            if(S(i).E>ETX)
                if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end

                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (S(i).EF<0)
```

```
                S(i).EF=0;

            end
        end



  %Election of Cluster Heads for Advanced nodes
  if( ( S(i).ENERGY==1 && ( temp_rand <= ( padv / ( 1 - padv * mod(r,round(1/padv)) )) ) )  )

            countCHs=countCHs+1;
            packets_TO_BS=packets_TO_BS+1;
            PACKETS_TO_BS(r+1)=packets_TO_BS;

            S(i).type='C';
            S(i).G=100;
            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 );
            C(cluster).distance=distance;
            C(cluster).id=i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;

            %Calculation of Energy dissipated
            distance;
            if (distance>do)
                S(i).EF=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
                S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*( distance*distance*distance*distance ));
```

```
        if(S(i).E>ETX)
            if(S(i).E>ETRX)
                pt=pt+1;
                pr=pr+1;
                p_t(r+1)=pt;
                p_r(r+1)=pr;
            end

            if(S(i).E<ETRX)

                pt=pt+1;

                p_t(r+1)=pt;

                end

            end
        end
        if (distance<=do)
            S(i).EF=S(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance * distance ));
            S(i).E=S(i).E- ( (ETX+EDA)*(4000)  + Efs*4000*( distance * distance ));
       if(S(i).E>ETX)
            if(S(i).E>ETRX)
                pt=pt+1;
                pr=pr+1;
                p_t(r+1)=pt;
                p_r(r+1)=pr;
            end

            if(S(i).E<ETRX)

                pt=pt+1;
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
                        p_t(r+1)=pt;

                        end

                    end
                end
                if (S(i).EF<0)
                    S(i).EF=0;

                end
            end

        end
      end
    end



    STATISTICS(r+1).CLUSTERHEADS=cluster-1;
    CLUSTERHS(r+1)=cluster-1;

    %Election of Associated Cluster Head for Normal Nodes
    for i=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-C(c).xd)^2 + (S(i).yd-C(c).yd)^2 ) );
               if ( temp<min_dis )
                   min_dis=temp;
```

Untitled × LEACHEREGG.m × SEPerGG.m ×

```
                min_dis_cluster=c;
            end
        end

        %Energy dissipated by associated Cluster Head
            min_dis;
            if (min_dis>do)
                S(i).E=S(i).E- ( ETX*(4000) + Emp*4000*( min_dis * min_dis * min_dis * min_dis));
            S(i).EF= S(i).EF;
            %S(i).EG= S(i).EG;
           if(S(i).E>ETX)
                if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end

                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (min_dis<=do)
                S(i).E=S(i).E- ( ETX*(4000) + Efs*4000*( min_dis * min_dis));

            S(i).EF= S(i).EF;
```

File Edit Text Go Cell Tools Debug Desktop Window Help

```
            if(S(i).E>ETX)
                if(S(i).E>ETRX)
                    pt=pt+1;
                    pr=pr+1;
                    p_t(r+1)=pt;
                    p_r(r+1)=pr;
                end

                if(S(i).E<ETRX)

                    pt=pt+1;

                    p_t(r+1)=pt;

                    end

                end
            end
            if (S(i).E<0)
                S(i).E=0;

            end
            U(i)= S(i).E;
            R(i)= Eo:Eo:Eo;

        if(min_dis>0)
            S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ( (ERX + EDA)*4000 );
         PACKETS_TO_CH(r+1)=n-dead-cluster+1;
        end

       S(i).min_dis=min_dis;
```

Untitled × LEACHEREGG.m × SEPerGG.m ×

File Edit Text Go Cell Tools Debug Desktop Window Help

```
        S(i).min_dis=min_dis;
        S(i).min_dis_cluster=min_dis_cluster;

     end
   end
 end
hold on;

countCHs;
rcountCHs=rcountCHs+countCHs;

end
t=toc
for i=1:1:n
    %P=[];
P(i)=[S(i).EF];%double array of energy left in normal node
Energy_Dissipated_By_Normal_Nodes(i)=R(i)-P(i);
if (Energy_Dissipated_By_Normal_Nodes(i)<0)
    Energy_Dissipated_By_Normal_Nodes(i)=0
end
end

Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
%TNN=sum(NN);
Total_Extra_Energy=(m*100)*(Eo*(a*m));
Total_Energy_Avaliable=sum(R)+Total_Extra_Energy;
Total_Energy_Dissipated_By_Normal_Nodes=sum(Energy_Dissipated_By_Normal_Nodes);
Total_Energy_Dissipated_By_Cluster_Heads=Total_Energy_Avaliable-Total_Energy_Dissipated_By_Normal_Nodes;
Total_Number_of_Cluster_Heads=sum(CLUSTERHS);
Average_Energy_Dissipated_Per_Cluster_Heads=Total_Energy_Dissipated_By_Cluster_Heads/Total_Number_of_Cluster_Heads;
Total_Number_of_Normal_Nodes=sum(Number_of_Normal_Nodes);
Average_Energy_Dissipated_Per_Normal_Nodes=Total_Energy_Dissipated_By_Normal_Nodes/Total_Number_of_Normal_Nodes;
```

Untitled | LEACHEREGG.m | SEPerGG.m

```
    end
end

Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
%TNN=sum(NN);
Total_Extra_Energy=(m*100)*(Eo*(a*m));
Total_Energy_Avaliable=sum(R)+Total_Extra_Energy;
Total_Energy_Dissipated_By_Normal_Nodes=sum(Energy_Dissipated_By_Normal_Nodes);
Total_Energy_Dissipated_By_Cluster_Heads=Total_Energy_Avaliable-Total_Energy_Dissipated_By_Normal_Nodes;
Total_Number_of_Cluster_Heads=sum(CLUSTERHS);
Average_Energy_Dissipated_Per_Cluster_Heads=Total_Energy_Dissipated_By_Cluster_Heads/Total_Number_of_Cluster_Heads;
Total_Number_of_Normal_Nodes=sum(Number_of_Normal_Nodes);
Average_Energy_Dissipated_Per_Normal_Nodes=Total_Energy_Dissipated_By_Normal_Nodes/Total_Number_of_Normal_Nodes;
dead_a;
dead_n;
dead_nodes=dead_a+dead_n
alive_nodes=n-dead_nodes
first_node_died=0;

PACKETS_TO_CH(r+1)
PACKETS_TO_BS(r+1)
figure(2);

plot (Round,Alive_N,'r')
xlabel('number of rounds')
ylabel('alives nodes')
```