Performance Analysis of Routing Protocols in Wireless Sensor Networks

By

Kyaw Min Htet 13507

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Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

SUPERVISOR: :Dr.Azrina Binti Abd Aziz

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CERTIFICATION OF APPROVAL

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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.

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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

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

$$E_{tx} = \begin{cases} E_{elec} * l + \varepsilon_{amp} * l * d^{2}, & \text{if } d < d_{0} \\ E_{elec} * l + \varepsilon_{amp} * l * d^{4}, & \text{if } d > d_{0} \end{cases}$$

$$E_{rx} = E_{elec} * l$$
(2.2)
$$(2.2)$$

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

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





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
$\epsilon_{\rm fs}$ (amplifier parameters of transmission of free-space models)	1x10 ⁻⁸ J/bit/m ²
ϵ_{amp} (amplifier parameters of transmission of two-ray models)	$1.3 \text{x} 10^{-15} \text{ J/bit/m}^2$
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]

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

Packet Loss Rate =
$$\frac{\text{Number of Packet Loss}}{\text{Number of Packet Transmitted}}$$
 (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.





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.

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7 APPENDIX

APPENDIX A

MATLAB CODE FOR LEACH ROUTING PROTOCOL

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+	L =	$-1.0 + \div 1.1 \times \% \% 0 $
1		
2	1. .	clear;
3		**************************************
4		
5		<pre>%Field Dimensions - x and y maximum (in meters)</pre>
6	10 111 1	xm=100;
7		ym=100;
8		<pre>%x and y Coordinates of the Sink</pre>
9	100	<pre>sink.x=0.5*xm;</pre>
10	8 .7 .	sink.y=0.5*ym;
11		
12		%Number of Nodes in the field
13	1000	n=100
14		
15		<pre>%Optimal Election Probability of a node to become cluster head/</pre>
16		p=0.1;
17		<pre>%Energy Model (all values in Joules)</pre>
18		%Initial Energy
19	-	Eo=0.5;
20		*Eelec=Etx=Erx
21		EIX=50*0.00000001;
22		EBW-5040 00000000 -
23		ERX=50~0.00000001;
24		EIRA-0.000;
25		Ffe=10*0 0000000000000000000000000000000000
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28		AData Aggregation Energy
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30		<pre>%maximum number of rounds</pre>
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+=	Ç ≣	-1.0 + \div 1.1 × $\%_{+}$ $\%_{+}$ 0_{-}
33		%Computation of do
34		do=sqrt(Efs/Emp);
35		%Creation of the random Sensor Network
36	22	figure(1);
37	- Ę]for i=1:1:n
38	8 8	S(i).xd=rand(1,1)*xm;
39	-	$XR(i) = S(i) \cdot xd;$
40	22	S(i).yd=rand(1,1)*ym;
41	400	$\underline{YR}(i) = S(i) \cdot yd;$
42	3 5	<u>S</u> (i).G=0;
43	3	<pre>%initially there are no cluster heads only nodes</pre>
44	-	<pre>S(i).type='N';</pre>
45	8	
46	10 10 16	<pre>temp_rnd0=i;</pre>
47		<pre>%Random Election of Normal Nodes</pre>
48		
49	31233	S(i).E=Eo;
50	3 5	S(i).ENERGY=0;
51		
52		- end
53	1000	S(n+1).xd=sink.x;
54		S(n+1).yd=sink.y;
55	-	plot(S(n+1).xd,S(n+1).yd,'x');
56		
57		
58		%First Iteration
59	-	figure(1);
60		Annual Sec. Clin
61		Scounter for the
62	8 75 6 2	Counters for CVa per yourd
63	100	recounter for the per round
04		rcouncens-o;

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65		cl	ust	er	=1;	-,			11.													
66	6				10																	
67	22	co	unt	CH	в;																	
68	-	rc	oun	tCl	Hs=	rco	unt	Hs+c	ount	CHs	;											
69	-	fl	ag_	fi	rst	_de	ad=(;														
70	-	ti	с																			
71	-	Ffo	r 1	=0	:1:	rma	х															
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74			\$Op	era	ati	on	for	epoc	:h													
75	-		if(moo	d(r	, r	ound	i(1/p))=	=0)												
76	(. 	Ē	f	or	i=	1:1	:n															
77	12 - 13				5 (i).	G=0;															
78	-				<u>S</u> (i).	c1=(;														
79	-	-	e	end																		
80	0. 11 .0	3	end	1																		
81																						
82	-	ho	ld	of	£;																	
83		14035																				
84		\$N	umb	er	of	de	ad r	lodes	3													
85	199 1. 99	de	ad=	•0;																		
86		\$N	umb	er	of	de	ad 7	dvar	iced	Nod	es											
87	-	de	ad_	a=(D;				12													
88		*N	umb	er	of	de	ad 1	lorma	I NO	des												
89	199 70 78 19	de	ad_	n=	D;																	
90			-	2355		12:000					- 10/2/18-1	-		-		12020		~	26/00			
91		\$C	oun	iter	TO	or	Dit	trar	ISMIT	ted	to	Da.	ses	Stat	cion	and	i to	0 01	us:	cer	Hea	ads,
92		pa	cke	CS.	_10	_ 85	-0;															
93	18 10 8 (8 <u>0</u> 8)	pa	cke	cs.	_10		-0;															
94		pr	-0;																			
95	_	pt	-0;				h i t		aw i -	****	+-	P-		-			1 -				U	1
96	8	°€C	oun	ice	L I	or	DIC	crar	ISMIT	ced	τđ	Das	363	Star	lion	and	I CO		.us	cer	nea	103

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1 🔁 🗔 👗 🖷 💼 🤊 (* )
- 1.0
                               x x x 0
                +
                    ÷ 1.1
                            x
97 -
        PACKETS TO CH(r+1)=0;
98 -
        PACKETS TO BS(r+1)=0;
        p r(r+1)=0;
99 -
100 -
        p t(r+1)=0;
101
102 -
        figure(1);
103
104 - 🗍 for i=1:1:n
105
            %checking if there is a dead node
106 -
            if (S(i).E<=0)
107 -
                plot(S(i).xd,S(i).yd,'red .');
108 -
                dead=dead+1;
109 -
                if(S(i).ENERGY==1)
110 -
                    dead a=dead a+1;
111 -
                end
112 -
                if(S(i).ENERGY==0)
113 -
                    dead n=dead n+1;
114 -
                end
115 -
                hold on;
116 -
            end
117 -
            if S(i).E>0
118 -
                S(i).type='N';
119 -
                if (S(i).ENERGY==0)
120 -
                plot(S(i).xd,S(i).yd,'o');
121 -
                text(S(i).xd,S(i).yd,num2str(i));%labeling the sensor nodes
122 -
                end
123
124 -
                hold on;
125 -
            end
126 -
       -end
127 -
        plot(S(n+1).xd,S(n+1).yd, 'x');
128
Untitled
       × LEACHERE.m* ×
```

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· += c=	-1.0 + \div 1.1 × $ \% \% \% $
130 -	STATISTICS(r+1).DEAD=dead;
131 -	<pre>DEAD(r+1)=dead;</pre>
132 -	<pre>DEAD_N(r+1)=dead_n;</pre>
133 -	<pre>DEAD_A(r+1)=dead_a;</pre>
134 -	Alive N(r+1)=n-dead;
135 -	Round (r+1)=r;
136	%When the first node dies
137 -	if (dead==1)
138 -	<pre>if(flag_first_dead==0)</pre>
139 -	first_dead=r
140 -	<pre>flag_first_dead=1;</pre>
141 -	end
142 -	end
143	
144 -	countCHs=0;
145 -	cluster=1;
146 - [for i=1:1:n
147 -	if(S(i).E>0)
148 -	temp_rand=rand;
149 -	if ((S(i).G)<=0)
150	
151	%Election of Cluster Heads
152 -	$if(temp_rand \leq (p/(1-p*mod(r,round(1/p)))))$
153 -	countCHs=countCHs+1;
154 -	<pre>packets_T0_BS=packets_T0_BS+1;</pre>
155 -	<pre>PACKETS TO BS(r+1)=packets_TO_BS;</pre>
156	
157 -	<pre>S(i).type='C';</pre>
158 -	S(i).G=round(1/p)-1;
159 -	<pre>C(cluster).xd=5(i).xd;</pre>
160 -	<pre>C(cluster).yd=S(i).yd;</pre>
161 -	plot(S(i).xd,S(i).yd,'k*');
Untitled	× LEACHERE.m* ×

File Edit Text	Go Cell Tools Debug Desktop Window Help
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⁺≣ Ç ≣ - 1.	$0 + \dot{+} \dot{+} 1.1 \times \% \% \% 0$
163 -	distance=sqrt((S(i).xd-(S(n+1).xd))^2 + (S(i).yd-(S(n+1).yd))^2);
164 -	C(cluster).distance=distance;
165 -	C(cluster).id=i;
166 -	χ (cluster)=S(i).xd;
167 -	$\underline{Y}(cluster)=S(i).yd;$
168 -	cluster=cluster+1;
169	
170	<pre>%Calculation of Energy dissipated</pre>
171 -	distance;
L72 -	if (distance>do)
L73 -	<pre>S(i).EF=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance))</pre>
L74 -	<pre>S(i).E=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance));</pre>
.75 -	if(S(i).E>ETX)
L76 -	<pre>if(S(i).E>ETRX)</pre>
177 -	pt=pt+1;
178 -	pr=pr+1;
179 -	<pre>p_t(r+1)=pt;</pre>
L80 -	<u>p_r(r+1)=pr;</u>
181 -	end
182	
183 -	if(S(i).E <etrx)< td=""></etrx)<>
.84	
.85 -	pt=pt+1;
.86	
L87 —	$p_t(r+1) = pt;$
.88	
.89 -	end
.90	
.91 -	end
192 -	end
193 -	if (distance<=do)
194 -	S(i).EF=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance))

100	$ \begin{bmatrix} \bullet \\ \bullet \end{bmatrix} & \blacksquare & \blacksquare & \checkmark & \frown & \blacksquare & \blacksquare$
· • 🖶 🚛	-1.0 + \div 1.1 × $\%_{+}^{\%}$ 0
195 -	S(i).E=S(i).E- ((ETX+EDA)*(4000) + Efs*4000*(distance * distance));
196 -	if(S(i).E>ETX)
197 -	<pre>if(S(i).E>ETRX)</pre>
198 -	pt=pt+1;
199 -	pr=pr+1;
200 -	<pre>p_t(r+1)=pt;</pre>
201 -	<u>p_r(r+1)=pr;</u>
202 -	end
203 -	<pre>if(S(i).E<etrx)< pre=""></etrx)<></pre>
204	
205 -	pt=pt+1;
206	
207 -	$\underline{p}_{t}(r+1) = pt;$
208	
209 -	end
210	
211 -	end
212 -	end
213 -	if(S(i).EF<0)
214 -	S(i).EF=0;
215 -	end
216 -	end
217	
218 -	end
219 -	end
220 -	- end
221	
222 -	<pre>STATISTICS(r+1).CLUSTERHEADS=cluster-1;</pre>
223 -	CLUSTERHS(r+1)=cluster-1;
224	
225	%Election of Associated Cluster Head for Normal Nodes
226 -	- for i=1:1:n
Untitled	x IFACHERE.m* x

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*= 🖷	-1.0 + $+$ \div 1.1 x $ \% \% \% $
227 -	if (S(i).type=='N' && S(i).E>0)
228 -	if(cluster-1>=1)
229 -	min_dis=sqrt((S(i).xd-S(n+1).xd)^2 + (S(i).yd-S(n+1).yd)^2);
230 -	<pre>min_dis_cluster=1;</pre>
231 - [for c=1:1:cluster-1
232 -	temp=min(min_dis,sqrt((S(i).xd-C(c).xd)^2 + (S(i).yd-C(c).yd)^2));
233 -	if (temp <min_dis)<="" td=""></min_dis>
234 -	min_dis=temp;
235 -	<pre>min_dis_cluster=c;</pre>
236 -	end
237 -	end
238	
239	<pre>%Energy dissipated by associated Cluster Head</pre>
240 -	min_dis;
241 -	if (min_dis>do)
242 -	<pre>S(i).E=S(i).E- (ETX*(4000) + Emp*4000*(min_dis * min_dis * min_dis * min_dis));</pre>
243 -	$\underline{S}(i)$.EF= $S(i)$.EF;
244 -	if(S(i).E>ETX)
245 -	if(S(i).E>ETRX)
246 -	pt=pt+1;
247 -	pr=pr+1;
248 -	p_t(r+1)=pt;
249 -	<u>p_r</u> (r+1)=pr;
250 -	end
251 -	<pre>if(S(i).E<etrx)< pre=""></etrx)<></pre>
252	
253 -	pt=pt+1;
254	
255 -	$\underline{p_t}(r+1) = pt;$
256	
257 -	end
258	
Untitled	× LEACHERE.m* ×

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+≣ ⊑		-	1.0	2	+		1.1	×	% [%] +	×%	0			10													1000
258		1					-				177																
259 -	5						e	nd																			
260																											
261 -	8					e	nd																				
262 -	ŝ.					i	f (m	in_d	is<=	do)																	
263 -	5						S	(i).	E=S (i).	E-	(E	TX*	(40	00)	+	Efs	*4(000	* (min	_di	s *	mi	n_c	lis));
264 -	ę.					S	(i).	EF=	S(i)	.EF	;																
265 -	8					į	f(S(i).E	>ETX	()																	
266 -	ŝ					i	f(S(i).E	>ETF	X)																	
267 -	5							р	t=pt	+1;																	
268 -	ę.							р	r=pr	+1;																	
269 -	8							p	t(r	+1)	=pt	;															
270 -	ŝ							p	r(1	:+1)	=pr	;															
271 -	5						e	nd																			
272 -	ę.						i	f(S(i).E	<et< td=""><td>RX)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></et<>	RX)																
273																											
274 -	ŝ							р	t=pt	+1;																	
275																											
276 -	6							P	t(r	:+1)	=pt	;															
277								100	1																		
278 -	ŝ							e	nd																		
279																											
280 -	ŝ						e	nd																			
281 -	8					e	nd																				
282 -	ŝ					i	f (S	(i).	E<0)																		
283 -	5						S	(i).	E=0;																		
284								3																			
285 -	8					e	nd																				
286 -	ŝ					U	(i)=	S(i).E;																		
287 -						R	(i)=	Eo:	Eo:E	o;																	
288 -	ŝ					EC	(i)=	R(i) –U (i);																	
289 -	8					TE	C=su	m (EC);																		
200 -	ed	×	IFA	CHE	RFm	тс * ,	HS=e	11m /C	LUST	FDH	51.																

-1.0 + \div 1.1 × $\%^{\circ}_{*}$ $\%^{\circ}_{*}$ \bigcirc
TEC=sum (EC);
TCHS=sum(CLUSTERHS);
if(min_dis>0)
<pre>S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ((ERX + EDA)*4000);</pre>
PACKETS TO CH(r+1)=n-dead-cluster+1;
end
S(i).min_dis=min_dis;
<pre>S(i).min_dis_cluster=min_dis_cluster;</pre>
end
end
- end
hold on;
countCHs;
rcountCHs=rcountCHs;
end
t <mark>=</mark> toc
for i=1:1:n
<pre>P(i)=[S(i).EF];%double array of energy left in normal node</pre>
<pre>Energy Dissipated By Normal Nodes(i)=R(i)-P(i);</pre>
end
Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
<pre>%TNN=sum(NN);</pre>
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;

	-1.0 + $\div 1.1$ × $\%^{2}$ $\%^{2}$ 0
311 -	P(i)=[S(i).EF];%double array of energy left in normal node
312 -	<pre>Energy Dissipated By Normal Nodes(i)=R(i)-P(i);</pre>
313 -	- end
314 -	Number of Normal Nodes=Alive N-CLUSTERHS;
315	<pre>\$TNN=sum(NN);</pre>
316 -	Total Energy Avaliable=sum(R);
317 -	Total Energy Dissipated By Normal Nodes=sum(Energy Dissipated By Normal Nodes);
318 -	Total Energy Dissipated By Cluster Heads=Total Energy Avaliable-Total Energy Dissipated By Normal Nodes;
319 -	Total Number of Cluster Heads=sum(CLUSTERHS);
320 -	Average Energy Dissipated Per Cluster Heads=Total Energy Dissipated By Cluster Heads/Total Number of Cluster Heads;
321 -	Total Number of Normal Nodes=sum(Number of Normal Nodes);
322 -	Average Energy Dissipated Per Normal Nodes=Total Energy Dissipated By Normal Nodes/Total Number of Normal Nodes;
323 -	dead a;
324 -	dead n;
325 -	dead nodes=dead a+dead n;
326 -	alive nodes=n-dead nodes;
327 -	first node died=0;
328	
329	
330 -	figure(2);
331	
332 -	plot (Round, Alive N, 'r')
333 -	xlabel('number of rounds')
334 -	ylabel('alives nodes')
335	
336	
337	
338	
339	
340	
341	
342	

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APPENDIX B

MATLAB CODE FOR SEP ROUTING PROTOCOL

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+=	⊊≣	-1.0 + $\div 1.1$ × $\%_{+}^{\%}$ $\%_{-}^{\%}$ 0
1		
2	-	clear;
3		
4		%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
5		
6		%Field Dimensions - x and y maximum (in meters)
7		xm=100;
8	100	ym=100;
9		
10		%x and y Coordinates of the Sink
11	- 7 7	sink.x=0.5*xm;
12	-	sink.y=0.5*ym;
13		investment with exemption bard charge investment
14		%Number of Nodes in the field
15		n=100;
16		
1/		SUPTIMAL Election Propability of a node
10		sto become cluster nead
20		p=0.1,
21		SEnergy Model (all values in Joules)
22		%Initial Energy
23	_	Eo=0.5;
24		%Eelec=Etx=Erx
25	-	ETX=50*0.00000001;
26	-	ERX=50*0.00000001;
27	-	ETRX=0.005;
28		%Transmit Amplifier types
29		Efs=10*0.00000000001;
30	-	Emp=0.0013*0.0000000001;
31		%Data Aggregation Energy
32	-	EDA=5*0.00000001;
Unt	titled	x LEACHEREGG.m x SEPerGG.m x

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: "	61	📓 🔏 ங 🛍 🤊 (*) 🍓 🖅 + 🚧 🖛 🗰 fil, 📔 * 🛃 👘 🛍 🛍 Stack: Base 🗸
+=	Ç,	$-1.0 + \div 1.1 \times \%^{\%}_{+} \%^{\%}_{-} $
34		%Values for Hetereogeneity
35		%Percentage of nodes than are advanced
36	-	m=0.1;
37		%\alpha
38	-	a=1;
39		
40		%maximum number of rounds
41	-	rmax=2000;
42		
43		
44		**************************************
45		
46		%Computation of do
47	-	do=sqrt(Efs/Emp);
48		
49		Screation of the random Sensor Network
50	- -	Ilgure(1);
51		C(i) ud=mand(1, 1) turn
52		$S(i) \cdot xd - rand(i, i) \cdot xm;$
55	_	S(i) ud=rand(1, 1) *um.
55		VP(i) = S(i) vd·
56	_	S(i) G=0:
57		Sinitially there are no cluster heads only nodes
58		S(i).tvpe='N';
59		
60	-	temp rnd0=i;
61		%Random Election of Normal Nodes
62	-	if (temp_rnd0>=m*n+1)
63		S(i).E=Eo;
64	-	S(i).ENERGY=0;
65		<pre>%%%%plot(S(i).xd,S(i).yd,'o');</pre>
Un	titled	× LEACHEREGG.m × SEPerGG.m ×

1	6	📓 👗 🍡 🖏 🤊 🕫 🍓 🖅 - 🕅 🖛 🜩 ft, 💽 - 🔁 🏖 🗐 👘 🗊 🚛 🏭 Stack: Base 🗸
+	Ç.	$-1.0 + \div 1.1 \times \% \% \% 0$
66	-	hold Divide value near cursor and evaluate cell (Ctrl+NumPad /)
67	-	end
68		<pre>%Random Election of Advanced Nodes</pre>
69	-	if (temp_rnd0 <m*n+1)< td=""></m*n+1)<>
70	-	$S(i) \cdot E = Eo * (1 + (a))$
71	-	S(i).ENERGY=1;
72		<pre>%%%%plot(S(i).xd,S(i).yd,'+');</pre>
73	-	hold on;
74	-	end
75	-	- end
76		
77	-	S(n+1).xd=sink.x;
78	—	S(n+1).yd=sink.y;
79	-	plot(S(n+1).xd,S(n+1).yd, 'x');
80		
81		
82		%First Iteration
83	-	<pre>figure(1);</pre>
84		
85		%counter for CHs
86	-	countCHs=0;
87		%counter for CHs per round
88	-	rcountCHs=0;
89	-	cluster=1;
90		
91	-	countCHs;
92		rcountCHs=rcountCHs;
93	-	<pre>flag_first_dead=0;</pre>
94	-	tic
95	-	for r=0:1:rmax
96	-	r
97		
: Un	titled	× LEACHEREGG.m × SEPerGG.m ×

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+=	대	-1.0 + $\div 1.1$ x $\%_{+}^{\%}$ 0
98		SElection Probability for Normal Nodes
99		pnrm=(p/ (1+a*m));
100		%Election Probability for Advanced Nodes
101		padv= (p*(1+a)/(1+a*m));
102		
103		%Operation for heterogeneous epoch
104		<pre>if(mod(r, round(1/pnrm))==0)</pre>
105		for i=1:1:n
106		S(i).G=0;
107		S(i).cl=0;
108		- end
109	-	end
110		
111		%Operations for sub-epochs
112		<pre>if(mod(r, round(1/padv))==0)</pre>
113		for i=1:1:n
114	1.57	<pre>if(S(i).ENERGY==1)</pre>
115		S(i).G=0;
116		S(i).cl=0;
117		end
118	1.57	end
119	- 77	end
120		
121		
122		hold off;
123		
124		%Number of dead nodes
125		dead=0;
126		%Number of dead Advanced Nodes
127		dead_a=0;
128		%Number of dead Normal Nodes
129		dead_n=0;
1 20		

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: +e ç		- 1.0 + ÷ 1.1 × % % 0
131		%counter for bit transmitted to Bases Station and to Cluster Heads
132 -	8	packets TO BS=0;
133 -	88	packets TO CH=0;
134 -	83	pr=0;
135 -	83	pt=0;
136		%counter for bit transmitted to Bases Station and to Cluster Heads
137		%per round
138 -	23	PACKETS TO CH(r+1)=0;
139 -	8	PACKETS TO BS(r+1)=0;
140 -	85	p_r(r+1)=0;
141 -	8	p_t(r+1)=0;
142		
143 -	8	figure(1);
144		
145 -	Ę	for i=1:1:n
146		<pre>%checking if there is a dead node</pre>
147 -	8	if (S(i).E<=0)
148 -	8	<pre>plot(S(i).xd,S(i).yd,'red .');</pre>
149 -		<pre>dead=dead+1;</pre>
150 -	83	<pre>if(S(i).ENERGY==1)</pre>
151 -	83	<pre>dead_a=dead_a+1;</pre>
152 -	8	end
153 -		if(S(i).ENERGY==0)
154 -	83 -	<pre>dead_n=dead_n+1;</pre>
155 -	3	end
156 -	85	hold on;
157 -	8	end
158 -	55	if S(i).E>0
159 -	83	<u>S</u> (i).type='N';
160 -	8	<pre>if (S(i).ENERGY==0)</pre>
161 -	8	<pre>plot(S(i).xd,S(i).yd,'o');</pre>
162 -		<pre>text(S(i).xd,S(i).yd,num2str(i));%labeling the sensor nodes</pre>
Untitle	ed	× LEACHEREGG.m × SEPerGG.m ×

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1	C	📓 🕹 ங 🛍 🤊 (° 🍪 🖅 • 🏘 🖛 🔿 fli, 돈 • 🔁 🖈 🖷 🛍 🕼 🕼 🛔 Stack: Base 🗸
+=	¢#	-1.0 $+$ \div 1.1 \times $\%$ $\%$ 0
163		if (S(i) ENERGY=1)
165	- 22	$\frac{11}{(S(1)) \cdot ENERGI-1)}$
166		pict(S(i), xd, S(i), yd, +), $text(S(i), yd, S(i), yd, num2etr(i)).$
167	-	and
168	-	hold on:
169	-	end
170		rend
171		plot(S(n+1),xd,S(n+1),vd,'x');
172		
173		
174	÷.	STATISTICS(r+1).DEAD=dead;
175		DEAD(r+1)=dead;
176		DEAD N(r+1)=dead n;
177	177	DEAD A(r+1)=dead a;
178		Alive N(r+1)=n-dead;
179	-	Round(r+1)=r;
180		%When the first node dies
181	772	if (dead==1)
182		<pre>if(flag_first_dead==0)</pre>
183		first_dead=r
184	375	toc
185		<pre>flag_first_dead=1;</pre>
186		end
187 188	-	end
189		countCHs=0;
190		cluster=1;
191		for i=1:1:n
192	-	if(S(i).E>0)
193	777	temp_rand=rand;
194		if ((S(i).G)<=0)
195		

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16	🖩 👗 🐂 🛍 🤊 🝽 🎒 🖅 - 🛤 🖛 🗰 flo, 🕨 - 🗟 🔏 🖷 🐃 🗊 🚛 🏭 Stack: Base 🗸 🥤 flo,
** •	-1.0 $+$ $\div 1.1$ x $\% \% \%$ 0
195	Splanting of Cluster Houds for name) adds
107 -	Selection of Charles is a horman hodes
109	In ((S()).EnkBi-o as (Cemp_Iand <- (phim / (I - phim / model, Found () phim) /) /)
199	COURTCHe=COURTCHe+1 ·
200 -	Darkets TO BS-markets TO BS+1.
200 -	Dickets TO BS(ril)=nackets TO BS.
202	
203 -	S(i).type='C':
204 -	S(i) = 00:
205 -	C(cluster).xd=S(i).xd;
206 -	C(cluster).vd=S(i).vd;
207 -	plot(S(i).xd,S(i).vd,'k*');
208	
209 -	distance=sqrt((5(i).xd-(5(n+1).xd))^2 + (5(i).yd-(5(n+1).yd))^2);
210 -	C(cluster).distance=distance;
211 -	C(cluster).id=i;
212 -	X(cluster)=S(i).xd;
213 -	Y(cluster)=S(i).yd;
214 -	cluster=cluster+1;
215	
216	<pre>%Calculation of Energy dissipated</pre>
217 -	distance;
218 -	if (distance>do)
219 -	<pre>S(i).EF=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance));</pre>
220 -	<pre>S(i).E=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance));</pre>
221 -	if(S(i).E>ETX)
222 -	if(S(i).E>ETRX)
223 -	pt=pt+1;
224 -	pr=pr+1;
225 -	<pre>p_t(r+1)=pt;</pre>
226 -	p_r(r+1)=pr;
227 -	end
Untitled	× LEACHEREGG.m × SEPergG.m ×

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*	唱	-1.0 + \div 1.1 × $\%$ $\%$ 0
220		
229	-	if(S(i).E <etrx)< td=""></etrx)<>
230		
231		pt=pt+1;
232		
233	-	p_t(r+1)=pt;
234		
235	-	end
236		
237	-	end
238	77	end
239	-	11 (distance<=do)
240	-	S(1).EF=S(1).E- ((ETX+EDA)*(4000) + Efs*4000*(distance * distance));
241	-	S(1) = S(1) = (ETX + EDA) * (4000) + EIS * 4000 * (distance * distance));
242	100	
243	100	II(S(1).E>EIKX)
244	-	pt=pt+1;
245	-	pr=pr+1;
240	2	$p_{12}(1+1) - p_{12}$
241		
240		end
250	_	if(S(i) EVETDY)
251		
252	_	nt=nt+1.
253		
254	_	p t(r+1)=pt:
255		
256	_	end
257		
258	-	end
259		end
260	-	if (S(i).EF<0)
Unt	itled	× LEACHEREGG.m × SEPerGG.m ×

106	📓 👗 🐂 🛍 🤊 (*) 🌭 🖅 - 🏘 🖛 🔿 fly 🕑 - 🗟 🗶 🖷 衢 🗊 🗐 🏙 Stack: Base 🗸 🥤 fly
+=	-1.0 + $\div 1.1$ × $\%_{+}^{*}$ $\%_{-}^{*}$ 0.
261 -	S(1).EF=0;
262	
263 -	end
264 -	end
265	
266	
267	
268	%Election of Cluster Heads for Advanced nodes
269 -	if((S(i).ENERGY==1 && (temp_rand <= (padv / (1 - padv * mod(r,round(1/padv)))))))
270	
271 -	countCHs=countCHs+1;
272 -	packets_TO_BS=packets_TO_BS+1;
273 -	PACKETS TO BS(r+1)=packets_TO_BS;
274	
275 -	<u>S</u> (i).type='C';
276 -	S(i).G=100;
277 -	<pre>C(cluster).xd=S(i).xd;</pre>
278 -	<pre>C(cluster).yd=S(i).yd;</pre>
279 -	plot(S(i).xd,S(i).yd,'k*');
280	
281 -	distance=sqrt((S(i).xd-(S(n+1).xd))^2 + (S(i).yd-(S(n+1).yd))^2);
282 -	<pre>C(cluster).distance;</pre>
283 -	<pre>C(cluster).id=i;</pre>
284 -	X(cluster) = S(i) . xd;
285 -	Y(cluster)=S(i).yd;
286 -	cluster=cluster+1;
287	
288	<pre>%Calculation of Energy dissipated</pre>
289 -	distance;
290 -	if (distance>do)
291 -	<pre>S(i).EF=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*distance));</pre>
292 -	<pre>S(i).E=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*(distance*distance*distance*);</pre>

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: 1	61	📓 🔏 ங 🛍 🤊 🍽 🌺 🖅 - 🏘 🖛 🗰 😥 💽 - 🛃 🏖 🖷 🎕 📑 🚛 🕼 Stack: Base 🗸 fiz
+0	ç#	-1.0 $+$ \div 1.1 \times $\%^{6}$ $\%^{6}$ 0
293	-	if(S(i).E>ETX)
294	-	if(S(i).E>ETRX)
295		pt=pt+1;
296	-	pr=pr+1;
297	-	<pre>p t(r+1)=pt;</pre>
298	-	p_r(r+1)=pr;
299	-	end
300		
301	-	<pre>if(S(i).E<etrx)< pre=""></etrx)<></pre>
302		
303		pt=pt+1;
304		1014 10042 10
305	-	<u>p</u> t(r+1)=pt;
306		
307	-	end
308		
309	2	end
211	2	end if (distance/=do)
312	_	$S(i) = ((FTY_FDA)*(4000) + Efe*4000*(distance * distance))$
313	_	S(i) = S(i) = ((FTX+FDA)*(4000) + Ffs*4000*(distance * distance));
314	_	if(S(i).E>ETX)
315	<u></u>	if (S(i).E>ETRX)
316	<u></u>	pt=pt+1;
317	-	pr=pr+1;
318	-	p t(r+1)=pt;
319	-	p r(r+1)=pr;
320	<u></u>	end
321		
322	-	<pre>if(S(i).E<etrx)< pre=""></etrx)<></pre>
323		
324		pt=pt+1;
Unt	itled	× LEACHEREGG.m × SEPerGG.m ×

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1	6	$\blacksquare \stackrel{*}{_{\!$	
+	5	$-1.0 + \div 1.1 \times \%^{6} \%^{6} 0$	
325			
326		<pre>p t(r+1)=pt;</pre>	
327			
328	-	end	
329			
330		end	
331		end	
332	-	if (S(i).EF<0)	
333	1	S(i).EF=0;	
334			
335		end	
336	-	end	
337			
338	- 27	end	
339		end	
340	-	- end	
341			
342			
343			
344	_	STATISTICS (r+1).CLUSTERHEADS=cluster-1;	
345	77	CLUSTERHS(r+1)=cluster-1;	
346		and the second of the second	
341		sclection of Associated Cluster head for Normal Nodes	
240		$\frac{1011-1}{10}$	
349	2	if (c)uster = 1 >= 1	
351		$\min_{i=1} (\text{subset}(1, S(i), \text{vd}_S(n+1), \text{vd})^2 + (S(i), \text{vd}_S(n+1), \text{vd})^2)$	
352	_	min_dis_sqlt($(5(1).xd-5(1+1).xd) \ge + (5(1).yd-5(1+1).yd) \ge)$, min_dis_cluster=1:	
353	_	for c=1:1:cluster-1	
354	_	temp=min(min dis sgrt($(S(i) \times d-C(c) \times d)^2 + (S(i) \times d-C(c) \times d)^2$))	
355	_	if $(\text{temp} \min \text{dis})$,
356	_	min dis=temp:	
110	itlad		
ont	idea		

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*= ,=	-1.0 + $\div 1.1$ x $\%^{+}_{+}\%^{-}_{-}$ 0
357 -	min_dis_cluster=c;
358 -	end
359 -	end
360	
361	<pre>%Energy dissipated by associated Cluster Head</pre>
362 -	min_dis;
363 -	if (min_dis>do)
364 -	S(i).E=S(i).E- (ETX*(4000) + Emp*4000*(min_dis * min_dis * min_dis * min_dis));
365 -	$\underline{S}(i)$.EF= $S(i)$.EF;
366	<pre>%S(i).EG= S(i).EG;</pre>
367 -	if (S(i).E>ETX)
368 -	if(S(i).E>ETRX)
369 -	pt=pt+1;
370 -	pr=pr+1;
371 -	$p_t(r+1)=pt;$
372 -	p_r(r+1)=pr;
373 -	end
374	
375 -	if(S(i).E <etrx)< td=""></etrx)<>
376	
377 -	pt=pt+1;
378	
379 -	$p_t(r+1)=pt;$
380	
381 -	end
382	
383 -	end
384 -	end
385 -	if (min_dis<=do)
386 -	S(i).E=S(i).E- (ETX*(4000) + Efs*4000*(min_dis * min_dis));
387	
388 -	S(i).EF= S(i).EF;

'lle	Euit	
1	61	
+	⊊≞	-1.0 + $\div 1.1$ × $9\%^{+}_{+}\%^{+}_{+}$ 0
89		
90	-	if(S(i).E>ETX)
91	-	if(S(i).E>ETRX)
92	-	pt=pt+1;
93	- 3	pr=pr+1;
94	-	p t(r+1)=pt;
95	_	p r(r+1)=pr;
96	-	end
97		
98	-	if(S(i).E < ETRX)
99		
00		pt=pt+1;
)1		
)2	-	p t(r+1) = pt;
03		
)4		end
05		
)6	-	end
17	-	end
8	-	if (S(i).E<0)
9	-	S(i).E=0;
10		
.1	-	end
.2	Ξ.	$\underline{U}(i) = S(i) \cdot E;$
13	- 3	$\underline{R}(i) = Eo:Eo:Eo;$
14		
15	-	if(min_dis>0)
16		<pre>S(C(min_dis_cluster).id).E = S(C(min_dis_cluster).id).E- ((ERX + EDA)*4000);</pre>
17	-	PACKETS TO CH(r+1)=n-dead-cluster+1;
18	-	end
19		
20	-	<pre>S(i).min_dis=min_dis;</pre>

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*=	-1.0 $+$ \div 1.1 \times $\%$ $\%$ 0
420 -	S(i).min dis=min dis;
421 -	S(i).min dis cluster=min dis cluster;
422	
423 -	end
424 -	end
425 -	- end
426 -	hold on;
427	
428 -	countCHs;
429 -	rcountCHs=rcountCHs+countCHs;
430	
431 -	- end
432 -	t=toc
433 -	for i=1:1:n
434	<pre>%P=[];</pre>
435 -	<pre>P(i)=[S(i).EF];%double array of energy left in normal node</pre>
436 -	<pre>Energy Dissipated By Normal Nodes(i)=R(i)-P(i);</pre>
437 -	<pre>if (Energy_Dissipated_By_Normal_Nodes(i)<0)</pre>
438 -	Energy Dissipated By Normal Nodes(i)=0
439 -	end
440 -	- end
441	
442 -	Number_of_Normal_Nodes=Alive_N-CLUSTERHS;
443	<pre>%TNN=sum(NN);</pre>
444 -	Total_Extra_Energy=(m*100)*(Eo*(a*m));
445 -	Total_Energy_Avaliable=sum(R)+Total_Extra_Energy;
446 -	Total_Energy_Dissipated_By_Normal_Nodes=sum(Energy_Dissipated_By_Normal_Nodes);
447 -	Total_Energy_Dissipated_By_Cluster_Heads=Total_Energy_Avaliable-Total_Energy_Dissipated_By_Normal_Nodes;
448 -	Total_Number_of_Cluster_Heads=sum(CLUSTERHS);
449 -	Average Energy Dissipated Per Cluster Heads=Total Energy Dissipated By Cluster Heads/Total Number of Cluster Heads;
450 -	Total_Number_of_Normal_Nodes=sum(Number_of_Normal_Nodes);
451 -	Average Energy Dissipated Per Normal Nodes=Total Energy Dissipated By Normal Nodes/Total Number of Normal Nodes;
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+= ,=	-1.0 $+$ \div 1.1 x $\%$ $\%$ 0
439 - 440 -	end -end
441	
442 -	Number of Normal Nodes=Alive N-CLUSTERHS;
445	SINN-SUM(NN); Total Evtra Energy=(m\$100)*(Eo\$(a\$m));
445 -	Total Energy Avalishle=gym/D/lTotal Evtra Energy.
445	Total Energy Available-Sum(K) Flotal Eatla Energy,
440	Total Energy Dissipated By Normal Nodes-Sum Energy Dissipated By Normal Nodes),
448 -	Total Number of Cluster Heade=sum (CLUSTERES) .
449 -	Average Energy Dissipated Per Cluster Heads=Total Energy Dissipated By Cluster Heads/Total Number of Cluster Heads:
450 -	Total Number of Normal Nodes=sum(Number of Normal Nodes);
451 -	Average Energy Dissipated Per Normal Nodes=Total Energy Dissipated By Normal Nodes/Total Number of Normal Nodes;
452 -	dead a;
453 -	dead n;
454 -	dead nodes=dead a+dead n
455 -	alive nodes=n-dead nodes
456 -	first node died=0;
457	
458 -	PACKETS_TO_CH(r+1)
459 -	PACKETS_TO_BS(r+1)
460 -	figure(2);
461	
462 -	plot (Round, Alive N, 'r')
463 -	<pre>xlabel('number of rounds')</pre>
464 -	ylabel('alives nodes')
465	
466	
467	
468	
469	
4/0	
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