IMPACT OF ENERGY LIFTIME USING HETROGENOUS WIRELESS SENSING NETWORKS

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CERTIFICATE

This is to certify that the work titled "**IMPACT OF ENERGY LIFTIME USING HETROGENOUS WIRELESS SENSING NETWORKS**" submitted by "**GAURAV GARG, KANWALJOT SINGH, ABHISHEK NARANG**" in partial fulfillment for the award of degree of Electronics and Communication B. Tech, of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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SUMMARY

Recent advancement in wireless communications and electronics has enabled the development of low-cost sensor networks. The sensor networks can be used for various application areas (e.g., health, military, home). For different application areas, there are different technical issues that researchers are currently resolving. Most of the attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture. In order to prolong the lifetime of the sensor nodes, optimum routing protocols are required to be design and implemented. Even though sensor networks are primarily designed for monitoring and reporting events, since they are application dependent, a single routing protocol cannot be efficient for sensor networks across all applications. In our project we are trying to deploy a heterogeneous wireless sensing network and calculating the energy lifetime of the deployed network by calculating the number of rounds for which the cluster head's energy is above the threshold.

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LIST OF SYMBOLS AND ACRONYMS

MECN	Minimum Energy Communication Network [1]
SMECN	Small Minimum Energy Communication Network [2]
GAF	Geographic Adaptive Fidelity [3]
GEAR	Geographical Energy Aware Routing [4]
TBF	Trajectory-Based Forwarding [5]
GeRaF	Geographic Random Forwarding [6]
SPIN	Sensor Protocols for Information via Negotiation [7,8]
COUGAR	COUGAR [11]
ACQUIRE	ACtive QUery forwarding In sensoR nEtwork [9]
DD	Directed Diffusion [12,13]
RR	Rumor Routing [14]
LEACH	Low Energy Adaptive Clustering Hierarchy [15,16]
PEGASIS	The Power Efficient Gathering in Sensor Information Systems [17]
HEED	Hybrid, Energy-Efficient Distributed Clustering [18,19]
TEEN	Threshold sensitive Energy Efficient sensor Network [20,21]

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CHAPTER 1

INTRODUCTION

Over the last few years wireless communication has become so much important that no one can imagine a world without it. There are various established technologies such as mobile phones and WLAN, but there is emergence of new approaches to the wireless communications being the ad-hoc and sensor networks which are the interesting potential applications of wireless communication. Ad-hoc networks consist of nodes which communicate through a radio and themselves providing communication's infrastructure. The communication between the two nodes is carried out either directly between them or through intermediate nodes relaying their message in case that both are not within mutual transmission range.

On the other hand, the continued advances in microsensor technology have resulted in the development and deployment of small low cost and low power sensing devices with computational "sensing" and communication capabilities. These advances make economically possible the deployment of large numbers of nodes to form a WSN that monitors a specified parameter. Even though, sensor nodes are not very accurate and reliable individually, their deployment in large number enhances their accuracy and reliability.

With the continuous advancement in the micro sensor technology, the small low cost and low power sensing devices with sensing and capability of communication have been developed. These developments have made deployment of large number of nodes to form a WSN network economical which can be used to monitor a specific parameter. Although sensors nodes are not much reliable but their deployment in large number can enhance thier reliability and accuracy.

The interest in the research and development of WSNs is due to their numerous advantages in front of other wireless technologies. They are easier, faster and cheaper to deploy than wired networks or other forms of wireless networks. They have good fault tolerance ability, because if a failure of one or few nodes occurs the network topology changes accordingly due to its self-configuring or self-organizing property and the operation of the network is not affected.

Some of the key challenges which wireless sensing networks is facing is dealing with the calability of network protocols to large number of nodes, design of simple and efficient protocols for different network operations, design of power-conserving protocols, design of data handling techniques including data querying, data mining, data fusion and data dissemination, localization techniques, time synchronization and development of exciting new applications that exploit the potential of wireless sensor networks.

Due to its great potential there are various scenarios where sensor networks can be used such as, disaster relief, community mesh networks, monitoring and surveillance, or data gathering, it is not surprising that there has recently been a flurry of research activity in the field.[22]

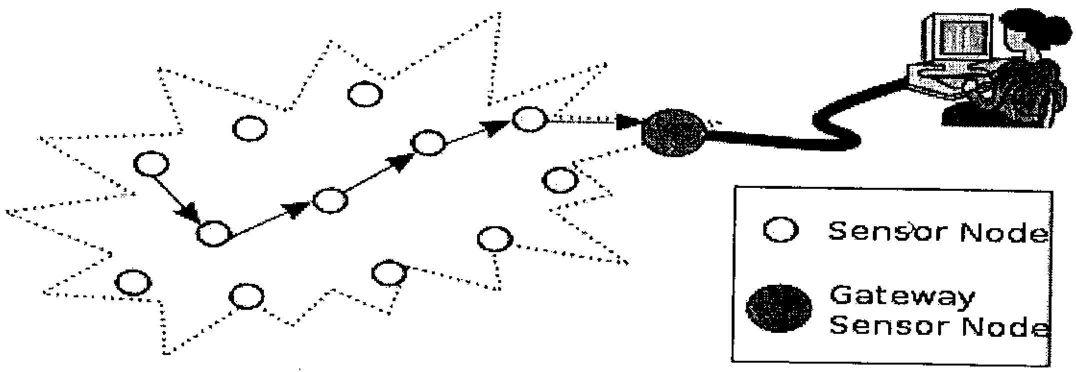


fig 1.1: routing in wireless sensing network

1.1 Wireless Sensor Networks

A Wireless Sensor Network (WSN) is supposed to be made up of a large number of sensors and at least one base station. The sensors are autonomous small devices with several constraints like the battery power, computation capacity, communication range and memory. They consist of transceivers to collect data from its surroundings and forward it to the base station, where the measured parameters can be stored and available for the end user.Mostly, the sensors forming are deployed randomly and left unattended to and are expected to perform their task efficiently. As a result of this random deployment, the WSN has usually varying degrees of node density along its area. Sensor networks are also energy constrained since the individual sensors, which the network is formed with, are extremely energy-constrained as well. The communication devices on these sensors are small and have limited power and range. [22]

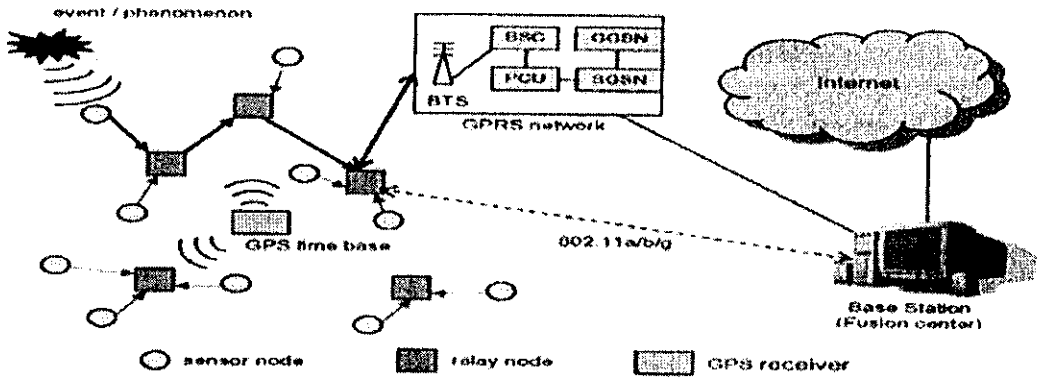


fig 1.2 : a typical wireless sensor network

Quite commonly WSNs is deploy networks need to be fault-tolerant so that the need for maintenance is minimized. Typically the network topology is continuously and dynamically changing, and it is actually not a desired solution to replenish it by infusing new sensors instead the depleted ones. A real and appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes.

In sensor networks, energy is a critical resource, while applications exhibit a limited set of characteristics. Thus, there is both a need and an opportunity to optimize the network architecture for the applications in order to minimize resource consumed. The requirements and limitations of sensor networks make their architecture and protocols both challenging and divergent from the needs of traditional Internet architecture.

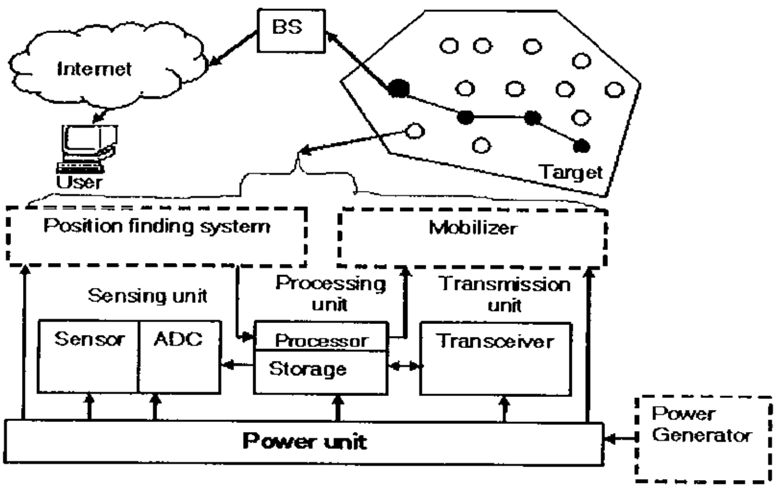


fig 1.3: Structural view of Sensor Network

Figure 1.3 shows the structural view of a sensor network in which sensor nodes are shown as small circles. Each node typically consists of the four components: sensor unit, central processing unit (CPU), power unit, and communication unit. They are assigned with different tasks. The sensor unit consists of sensor and ADC (Analog to Digital Converter). The sensor unit is responsible for collecting information as the ADC requests, and returning the analog data it sensed. ADC is a translator that tells the CPU what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit is tasked to receive command or query from and transmit the data from CPU to the outside world. CPU is the most complex unit. It interprets the command or query to ADC, monitors and controls power if necessary, processes received data, computes the next hop to the sink, etc.

Power unit supplies power to sensor unit, processing unit and communication unit. Each node may also consist of the two optional components namely Location finding system and mobilizer. If the user requires the knowledge of location with high accuracy then the node should pusses Location finding system and Mobilizer may be needed to move sensor nodes when it is required to carry out the assigned tasks.

1.2. Classification of Wireless Sensor Networks

In this subsection a simple classification of sensor networks based on their mode of functioning and the type of target application.

Proactive Networks

The nodes in this sort of network periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest. Hence, they provide a snapshot of the relevant parameters at regular intervals. They are well suited for applications requiring periodic data monitoring. For example protocol such as leach, pegasis.

Reactive Networks

The nodes of the networks according to this scheme react immediately to sudden and drastic changes in the value of a sensed attribute. They are well suited for time critical applications.

Hybrid Networks

The nodes in such a network not only react to time-critical situations, but also give an overall picture of the network at periodic intervals in a very energy efficient manner. Such a network enables the user to request past, present and future data from the network in the form of historical, one-time and persistent queries respectively. In our heterogeneous network, we considered this hybrid form of deployment and functioning.

1.3 Routing Models

All known routing protocols may be included into one of the following three models. This classification will facilitate the analysis of the protocols that have been taken into account in this work.

1.3.1 One - hop model

This is the simplest approach and represents direct communication as is shown in Figure1.4. In these networks every node transmits to the base station directly. This communication implies not only to be too expensive in terms of energy consumption, but it is also infeasible because nodes have limited transmission range. Most of the

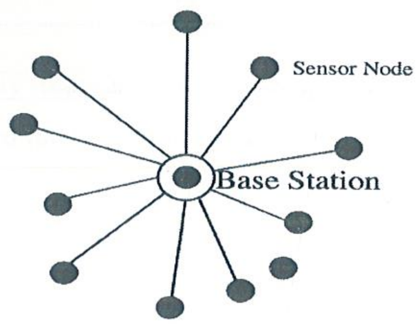


fig 1.4: One hop model

Nodes in networks with large area coverage usually are far enough thus their transmissions cannot reach the base station. Direct communication is not a feasible model for routing in WSN.

1.3.2 Multi-hop Planar Model

In this model, a node transmits to the base station by forwarding its data to one of its neighbors, which is closer to the base station. The latter passes on it to a neighbor that is even closer to the base station as is denoted in Figure 1.5 . Thereby the information travels from source to destination by hop from one node to another until it reaches the destination. Regarding to the energy and transmission range node limitations, this model is a viable approach. A number of protocols employ this approach, and some use other optimization techniques to enhance the efficiency of this model. One of these techniques is data aggregation used in all clustering-based routing protocol. Even though these optimization techniques improve the performance of this model, it is still a planar model.

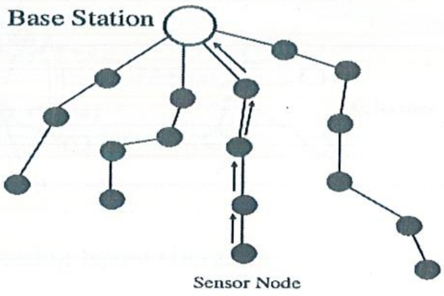


fig 1.5: multi hop planar model

In a network composed by thousands of sensors, this model will exhibit high data Dissemination latency due to the long time needed by the node information to arrive to the base station.

1.3.3 Clustering-based Hierarchical Model

A hierarchical approach for the network topology breaks the network into several areas called clusters as shown in Figure 1.6. Nodes are grouped depending on some parameter into clusters with a cluster head, which has the responsibility of routing the data from the cluster to other cluster heads or base stations. Data travels from a lower clustered layer to a higher one.

Data still hops from one node to another, but since it hops from one layer to another it covers larger distances and moves the data faster to the base station than in the multi-hop model. The latency in this model is theoretically much less than in the multi-hop model. Clustering provides inherent optimization capabilities at the cluster heads, what results in a more efficient and well structured network topology. This model is more suitable than the one-hop or multi-hop model.

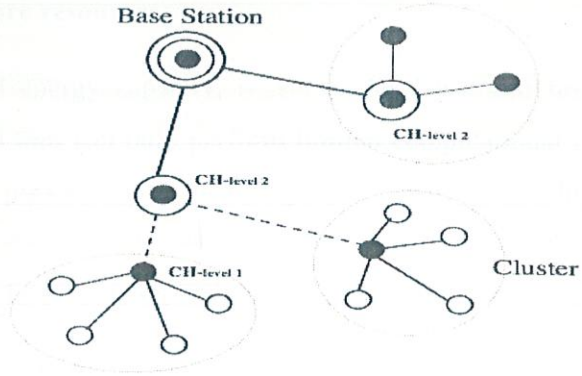


fig 1.6: Clustering-based Hierarchical Model

1.4 Design Factors

The design of routing protocols for WSNs is challenging because of several network constraints. WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit, and storage [6, 7]. The design challenges in sensor networks involve the following main aspects [6, 7, 8]:

1.4.1 Limited energy capacity

Since sensor nodes are battery powered, they have limited energy capacity. Energy poses a big challenge for network designers in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Thus, routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall.

1.4.2 Sensor locations

Another challenge that faces the design of routing protocols is to manage the locations of the sensors. Most of the proposed protocols assume that the sensors either are equipped with global positioning system (GPS) receivers or use some localization technique [9] to learn about their locations.

1.4.3 Limited hardware resources

In addition to limited energy capacity, sensor nodes have also limited processing and storage capacities, and thus can only perform limited computational functionalities. These hardware constraints present many challenges in software development and network protocol design for sensor networks, which must consider not only the energy constraint in sensor nodes, but also the processing and storage capacities of sensor nodes.

1.4.4 Massive and random node deployment

Sensor node deployment in WSNs is application dependent and can be either manual or random which finally affects the performance of the routing protocol. In most applications, sensor nodes can be scattered randomly in an intended area or dropped massively over an inaccessible or hostile region. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.

1.4.5 Network characteristics and unreliable environment

A sensor network usually operates in a dynamic and unreliable environment. The topology of a network, which is defined by the sensors and the communication links between the sensors, changes frequently due to sensor addition, deletion, node failures, damages, or energy depletion. Also, the sensor nodes are linked by a wireless medium, which is noisy, error prone, and time varying. Therefore, routing paths should consider network topology dynamics due to limited energy and sensor mobility as well as increasing the size of the network to maintain specific application requirements in terms of coverage and connectivity.

1.4.6 Data Aggregation

Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

1.4.7 Diverse sensing application requirements

Sensor networks have a wide range of diverse applications. No network protocol can meet the requirements of all applications. Therefore, the routing protocols should guarantee data delivery and its accuracy so that the sink can gather the required knowledge about the physical phenomenon on time.

1.4.8 Scalability

Routing protocols should be able to scale with the network size. Also, sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. Hence, communication links between sensors may not be symmetric, that is, a pair of sensors may not be able to have communication in both directions. This should be taken care of in the routing protocols.

1.4.9 Quality of service

In some applications, data should be delivered within a certain period of time from the moment it is sensed, or it will be useless. Therefore, bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As energy is depleted, the network may be required to reduce the quality of results in order to reduce energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

1.4.10 Transmission media

In a multihop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network. In general, the required bandwidth of sensor data will be low, on the order of 1–100 kb/s. Related to the transmission media is the design of MAC. One approach to MAC design for sensor networks is to use time division multiple access (TDMA)-based protocols that conserve more energy than contention based protocols like carrier sense multiple access (CSMA) (e.g., IEEE 802.11). Bluetooth technology [10] can also be used.

1.4.11 Connectivity

High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from shrinking due to sensor node failures. In addition, connectivity depends on the possibly random distribution of nodes.

CHAPTER 2

HOMOGENEOUS AND HETRGENENOUS NETWORKS

2.1 Homogeneous Sensor Networks

A homogeneous sensor network consists of identical nodes i.e. all the sensor nodes have same hardware complexity, battery energy and sensor range.

In a homogeneous network, it is evident that the cluster head nodes will be over-loaded with the long range transmissions to the re-mote base station, and the extra processing necessary for data aggregation and co-ordination of protocol. As a result the cluster head nodes expire before other nodes. However it is desirable to ensure that all the nodes run out of their battery at about the same time, so that very little residual energy is wasted when the system expires.

Using a homogeneous network and role rotation, the nodes should have capability of acting as cluster heads, and therefore should possess the necessary hardware capabilities. With the advancement in the wireless sensing networks (WSN) various kinds of application specific routing protocols have been developed. The Table 1 shows the comparison of existing routing protocols with the consideration of several design factors like Scalability, Power Usage, Mobility, Over-heads, Query-based, Data Aggregation and Localization.

2.2 **Routing Protocols for Homogeneous Networks**

Table 2.1 : Various Routing Protocols

Routing Protocols	classification	Scalability	Power Usage	Mobility	Over - heads	Query-based	Data aggregation	Localization
MECN	Location-based	No	Max	No	Moderate	No	No	Yes
SMECN	Location-based	No	Max	No	Moderate	No	No	Yes
GAF	Location-based	Good	Limited	Limited	Moderate	No	No	Yes
GEAR	Location-based	Limited	Limited	Limited	Moderate	No	No	Yes
GBF	Location-based	Limited	Limited	Limited	Moderate	Yes	No	Yes
GeRaF	Location-based	Limited	Limited	Limited	low	No	No	No
SPIN	Data-centric	Limited	Limited	Possible	low	Yes	Yes	No
DD	Data-centric	Limited	Limited	Limited	low	Yes	Yes	Yes
Rumor	Data-centric	Good	Low	Limited	low	Yes	Yes	No
COUGAR	Data-centric	Limited	Limited	no	High	Yes	Yes	No
ACQUIRE	Data-centric	Limited	Low	Limited	low	Yes	Yes	No
LEACH	Hierarchical	Good	Max	Fixed BS	High	No	Yes	Yes
PEGASIS	Hierarchical	Good	Max	Fixed BS	Low	No	No	Yes
HEED	Hierarchical	Good	Max	Fixed BS	Moderate	No	Yes	Yes
TEEN	Hierarchical	Good	Max	Fixed BS	High	No	Yes	Yes

1.Minimum energy communication network (MECN)[1] setup and maintains a minimum energy network for wireless networks by utilizing low power GPS. A minimum power topology for stationary nodes including a master node is found. MECN assumes a master-site as the information sink, which is always the case for sensor networks. The main idea of MECN is to find a sub-network, which will have less number of nodes and require less power for transmission between any two particular nodes.

2. Small minimum energy communication network (SMECN)[2]is an extension to MECN. In MECN, it is assumed that every node can transmit to every other node, which is not possible every time SMECN uses less energy than MECN and maintenance cost of the links is less. However, finding a sub-network with smaller number of edges introduces moreover head in the algorithm

3. Geographic adaptive fidelity (GAF)[3] is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well. GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area.

4. Geographic and Energy-Aware Routing (GEAR): GEAR [4] is an energy-efficient routing protocol proposed for routing queries to target regions in a sensor field, In GEAR, the sensors are

supposed to have localization hardware equipped, for example, a GPS unit or a localization system [10] so that they know their current positions. Furthermore, the sensors are aware of their

residual energy as well as the locations and residual energy of each of their neighbors. GEAR uses energy aware heuristics that are based on geographical information to select sensors to route

a packet toward its destination region. Then, GEAR uses a recursive geographic forwarding algorithm to disseminate the packet inside the target region.

5. Gradient-based routing(GBR)[5] is a slightly changed version of Directed Diffusion. The idea is to keep the number of hops when the interest is diffused through the network. Hence, each node can discover the minimum number of hops to the sink, which is called height of the node. The difference between anode's height and that of its neighbour is considered the gradient on that link. A packet is forwarded on a link with the largest gradient.

6. Geographic Random Forwarding (GeRaF): GeRaF was proposed by Zorzi and Rao [6], which uses geographic routing where a sensor acting as relay is not known a priori by a sender. There is no guarantee that a sender will always be able to forward the message toward its ultimate destination, that is, the sink. This is the reason that GeRaF is said to be best-effort forwarding. GeRaF assumes that all sensors are aware of their physical locations, as well as that of the sink. Although GeRaF integrates a geographical routing algorithm and an awake-sleep scheduling algorithm, the sensors are not required to keep track of the locations of their neighbors and their awake-sleep schedules

7. Sensor Protocols for Information via Negotiation (SPIN): SPIN [7,8] protocol was designed to improve classic flooding protocols and overcome the problems they may cause, for example, implosion and overlap. The SPIN protocols are resource aware and resource adaptive. The sensors running the SPIN protocols are able to compute the energy consumption required to compute, send, and receive data over the network. Thus, they can make informed decisions for efficient use of their own resources. The SPIN protocols are based on two key mechanisms namely negotiation and resource adaptation. SPIN enables the sensors to negotiate with each other before any data dissemination can occur in order to avoid injecting non-useful and redundant information in the network. SPIN uses meta-data as the descriptors of the data that the sensors want to disseminate. The notion of meta-data avoids the occurrence of overlap given sensors can name the interesting portion of the data they want to get. It may be noted here that the size of the meta-data should definitely be less than that of the corresponding sensor data. Contrary to the flooding technique, each sensor is aware of its resource consumption with the help of its own resource manager that is probed by the application before any data processing or transmission. This helps the sensors to monitor and adapt to any change in their own resources.

8. Cougar[11] is data-centric protocol which views the network as a huge distributed database system. The key idea is to use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors and so on. COUGAR utilizes in-network data aggregation to obtain more energy savings. The abstraction is supported through an additional query layer that lies between the network and application layers. COUGAR incorporates a architecture for the sensor database system where sensor nodes select a leader node to perform aggregation and transmit the data to the BS.

9. Acquire[9]:A fairly new data-centric mechanism for querying sensor networks is ACtive QUery forwarding. The approach views the sensor network as a distributed database and is well-suited for complex queries which consist of several sub queries. The query is forwarded by the sink and each node receiving the query, tries to respond partially by using its pre-cached in formation and forward it to another sensor. One of the main motivations for proposing ACQUIRE is to deal with one-shot, complex queries for data where a response can be provided by many nodes.

10. Direct Diffusion[12,13] is a popular data aggregation paradigm for WSNs. It is a data-centric and application-aware paradigm in the sense that all data generated by sensor nodes is named by attribute-value pairs. The main idea is to combine the data coming from different sources (in-network aggregation) by eliminating redundancy, minimizing the number of transmissions, thus saving network energy and prolonging its lifetime.

11. Rumor routing[14] is another variation of Directed Diffusion and is mainly intended for contexts in which geographic routing criteria are not applicable. Rumor routing is between event flooding and query flooding. The idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events. In order to flood events through the network, the rumor routing algorithm employs long-lived packets, called agents. When a node detects an event, it adds such event to its local table and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes.

12. Low-energy adaptive clustering hierarchy (LEACH)[15,16] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes.

13. PEGASIS [17] stands Power Efficient Gathering in Sensor Information Systems. It is the enhancement over LEACH protocol.Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbour and only one node is selected from that chain to transmit to the base station (sink).Gathered data moves from node to node, aggregated and eventually sent to the base station.

14. Hybrid, Energy-Efficient Distributed Clustering (HEED): HEED [18,19] extends the basic scheme of LEACH by using residual energy and node degree or density as a metric for cluster selection to achieve power balancing. It operates in multi-hop networks, using an adaptive transmission power in the inter-clustering communication. HEED was proposed with four primary goals namely (i) prolonging network lifetime by distributing energy consumption, (ii) terminating the clustering process within a constant number of iterations, (iii) minimizing control overhead, and (iv) producing well-distributed CHs and compact clusters. In HEED, the proposed algorithm periodically selects CHs according to a combination of two clustering parameters.

15.Threshold sensitive Energy Efficient sensor Network protocol (TEEN)[20,21] is a hierarchical protocol designed to be responsive to sudden changes in the sensed attributes such as temperature. Responsiveness is important for time-critical applications, in which the networks operated are in active mode. TEEN pursues a hierarchical approach along with the use of a data-centric mechanism. The sensor network architecture is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until base station (sink) is reached.

2.3 Heterogeneous wireless sensor network

In Heterogeneous wireless sensor network (heterogeneous WSN) different sensor nodes have different computing power and sensing range and therefore provide more flexibility in deployment. For example if there are two types of senor nodes: the high-end ones have higher process throughput and longer communication or sensing range; the low-end ones are much cheaper and with limited computation and communication/sensing abilities. A mixed deployment of these nodes can achieve a balance of performance and cost of WSN.As compared to homogeneous WSN, deployment and topology control are also more complex in heterogeneous wireless sensor network.

Node deployment in heterogeneous WSN has to consider the topology control between different types of sensor nodes. For example, to maintain a symmetric communication, the distance between high-end and low-end sensor nodes cannot be larger than the maximum communication range of the lower end. Also if the sensor nodes have different detection range, the sensor coverage area of low-end node cannot be fully covered by the high-end node.

In a Heterogeneous sensor network, two or more different types of nodes with different battery energy and functionality are used. The motivation being that the more complex hardware and the extra battery energy can be embedded in few cluster head nodes, thereby reducing the hardware cost of the rest of the network. However fixing the cluster head nodes means that role rotation is no longer possible. When the sensor nodes use single hopping to reach the cluster head, the nodes that are farthest from the cluster heads always spend more energy than the nodes that are closer to the cluster heads. On the other hand when nodes use multi-hopping to reach the cluster head, the nodes that are closest to the cluster head have the highest energy burden due to relaying. Consequently there always exists a non-uniform energy drainage pattern in the network.

In Heterogeneity sensor network architecture, there are two types of sensors namely line-powered sensors which have no energy constraint, and the battery-powered sensors having limited lifetime. Uses of heterogeneity in WSNs to extend network lifetime and present a few routing protocols. IDSQ, CADR, CHR are few Heterogeneity-based Protocols.

2.4 Routing networks of Heterogeneous networks

1.Information-Driven Sensor Query (IDSQ): IDSQ addresses the problem of heterogeneous WSNs of maximizing information gain and minimizing detection latency and energy consumption for target localization and tracking through dynamic sensor querying and data routing. In IDSQ protocol, first step is to select a sensor as leader from the cluster of sensors. This leader will be responsible for selecting optimal sensors based on some information utility measure.

2.Cluster-Head Relay Routing (CHR):CHR routing protocol uses two types of sensors to form a heterogeneous network with a single sink: a large number of low-end sensors, denoted by *L-sensors,* and a small number of powerful high-end sensors, denoted by H-sensors. Both types of sensors are static and aware of their locations using some location service. The CHR protocol partitions the heterogeneous network into groups of sensors (or clusters), each being composed of L-sensors and led by an H-sensor. Within a cluster, the

L-sensors are in charge of sensing the underlying environment and forwarding data packets originated by other L-sensors toward their cluster head in a multi hop fashion. The H-sensors, on the other hand, are responsible for data fusion within their own clusters and forwarding aggregated data packets originated from other cluster heads toward the sink in a multi hop fashion using only cluster heads.

CHAPTER 3

ENERGY CONSIDERATION FOR A WIRELESS SENSING NETWORK

3.1 Design factor: Energy

Microsensor networks can contain hundreds or thousands of sensing nodes to sense the data on the wireless links. So to fulfill this need these nodes are made as cheap and energy-efficient as possible and are deployed in large numbers to obtain high quality results. Network protocols which are discussed above must be designed to achieve fault tolerance in the presence of individual node failure while minimizing energy consumption. In addition, since the limited wireless channel bandwidth must be shared among all the sensors in the network, routing protocols for these networks should be able to perform local collaboration to reduce bandwidth requirements. Eventually, the data being sensed by the nodes in the network must be transmitted to a control center or base station, where the end-user can access the data. There are many possible models for these microsensor networks. In our work, we consider microsensor networks where, the base station is fixed and located far from the sensors. The node deployment is preplanned in which cluster head is at the fixed location from the base station and other sensors are deployed randomly around the cluster head. We consider a heterogeneous network deployment model and the range for cluster head is 100 meters and the range of other sensors in 20 meters. The application of wireless sensor network which we considered for our work is monitoring of the boundaries of long and wide field region.

The communication between the sensor nodes and the base station is expensive, and there are no "high-energy" nodes through which communication can proceed. This is the framework for MIT's-AMPS project, which focuses on innovative energy-optimized solutions at all levels of the system hierarchy, from the physical layer and communication protocols up to the application layer and efficient DSP design for micro sensor nodes. Sensor networks contain too much data for an end-user to process. Therefore, an automated method of combining or aggregating the data into a small set of meaningful information is required [24, 25]. In addition to helping avoid information overload, data aggregation, also known as data fusion, can combine several unreliable data measurements to produce a more accurate signal by enhancing the common signal and reducing the uncorrelated noise. The classification performed on the aggregated data might be performed by a human operator or automatically. Both the method of performing data aggregation and the classification algorithm are application-specific.

3.2 First order energy model

The use of clusters for transmitting data to the base station leverages the advantages of small transmit distances for most nodes, requiring only a few nodes to transmit far distances to the base station. In First order model, there is a great deal of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in the transmit and receive modes, will change the advantages of different protocols. In our work, we assume a simple model where the radio dissipates 50nJ/bit to run the transmitter or receiver circuitry and 100pJ/bit/m_ for the transmit amplifier to achieve an acceptable (see Figure 1 and Table 1). These parameters are slightly better than the current state-of-the-art in radio design. For example, the Bluetooth initiative [23] specifies 700 Kbps radios that operate at 2.7 V and 30 mA, or 115 nJ/bit. Receiving a message is not a low cost operation; the protocols should thus try to minimize not only the transmit distances but also the number of transmit and receive operations for each message.

Thus, to transmit a 3 -bit message a distance 4 using our radio model, the radio expends:

$$E_T(k,d) = E_{TRADIO}(k,d) + E_{TAM}(k,d)$$

$$E_T(k,d) = E_{TRADIO} * k + \in_{TAM} * k * d^2 \qquad (1)$$

and to receive this message, the radio expends:

$$E_R(k) = E_{RRADIO}(k)$$

$$E_R(k) = E_{RRADIO} * k \quad (2)$$

We are here concerned with the energy lifetime of the cluster head only because, if sensors other then the cluster head die the message from that cluster will still reach to the base station through the other sensors via cluster head. But if a cluster head dies then the whole cluster will not work and is no use to the base station.

OPERATION	ENERGY DISSIPATED
TRANSMITTER ELECTRONICS(E_{TRADIO}) REDCEIVER ELECTRONICS (E_{RRADIO}) ($E_{TRADIO} = E_{RRADIO} = E_{RADIO}$)	50nJ/bit
TRANSMIT AMPLIFIER(ϵ_{TAM})	100pJ/bit/m^2

TABLE 3.1:RADIO CHARACTERSITCS

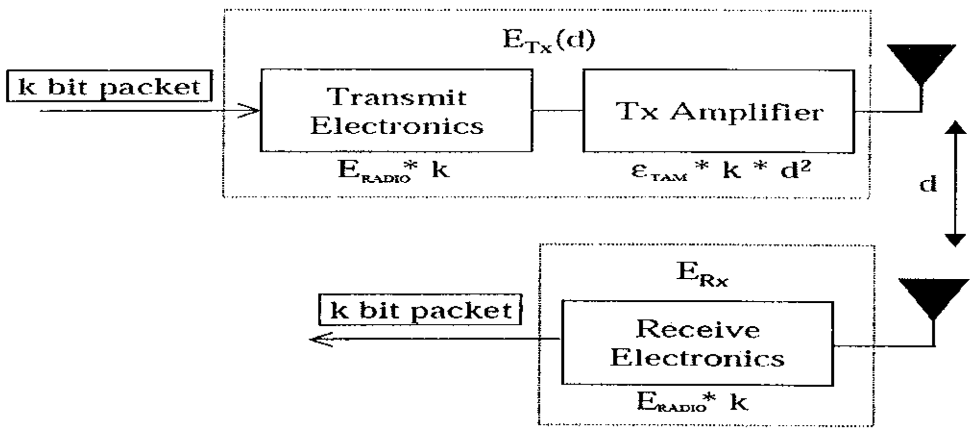
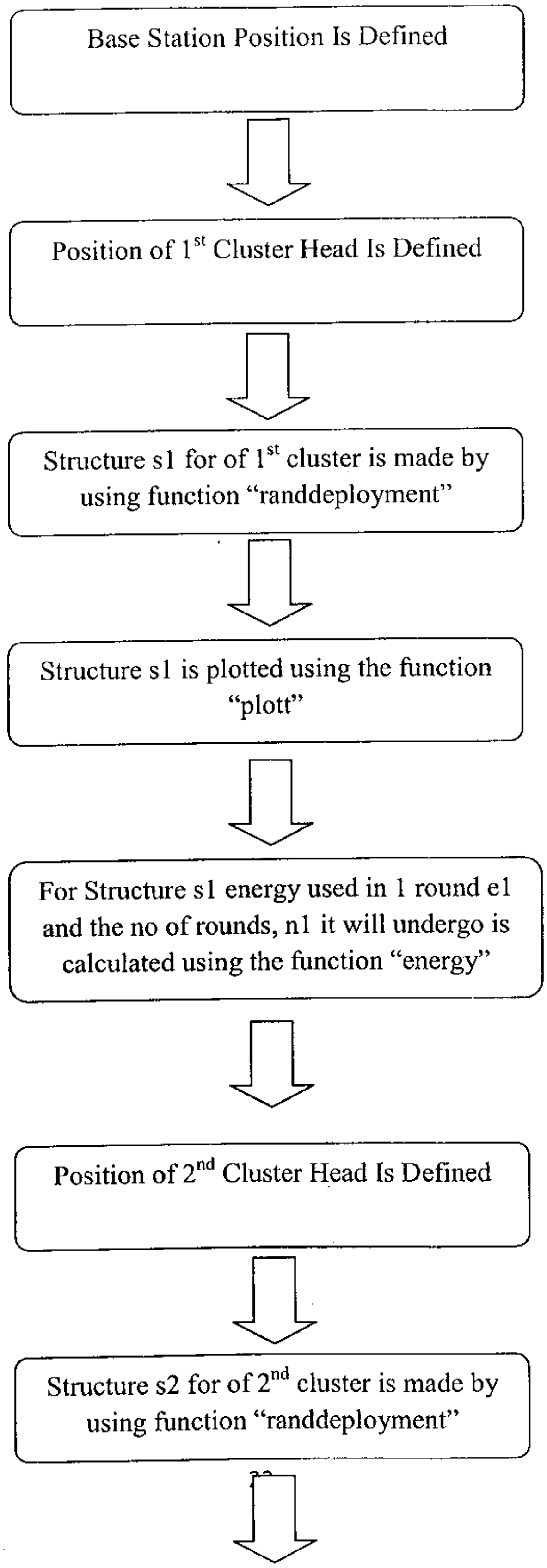


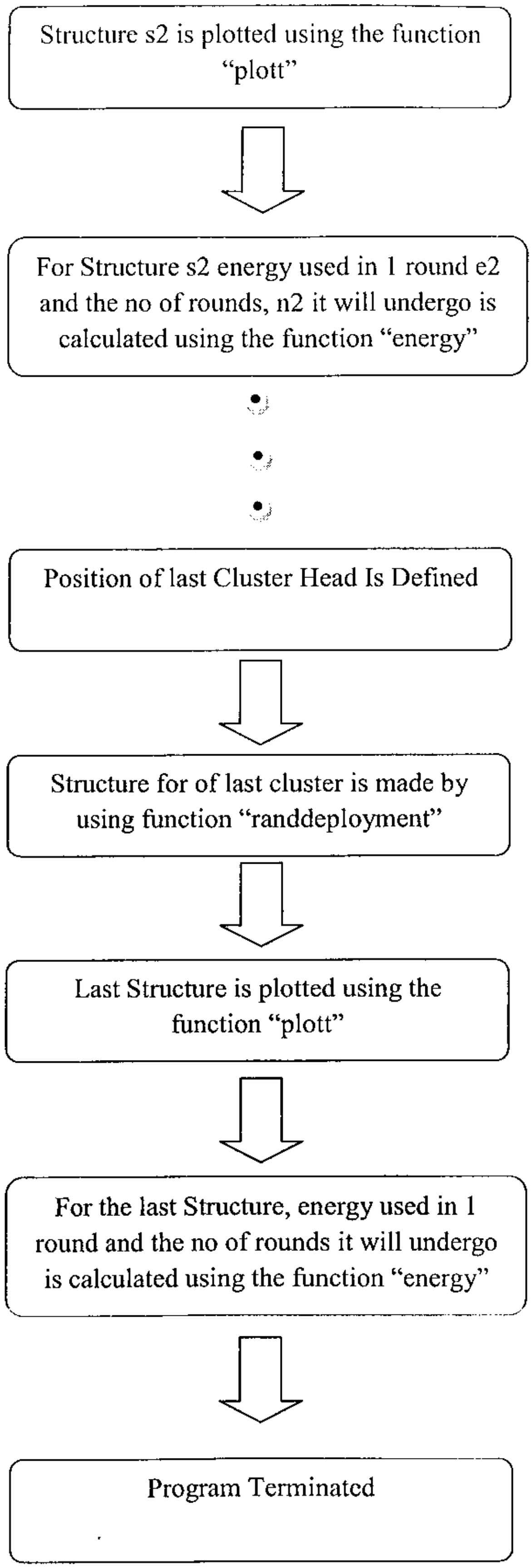
Fig:3.1 first order energy model

3.3 Flow Chart

Following (on the next page) is the flow chart(fig: 3.2) of the showing the algorithm which we follow for the deployment and calculation of the energy lifetime of the cluster head of each cluster..

FLOW CHART OF THE PROGRAM




Structure s2 is plotted using the function "plott"
For Structure s2 energy used in 1 round e2 and the no of rounds, n2 it will undergo is calculated using the function "energy"
Position of last Cluster Head Is Defined
Structure for of last cluster is made by using function "randdeployment"
Last Structure is plotted using the function "plott"
For the last Structure, energy used in 1 round and the no of rounds it will undergo is calculated using the function "energy"
Program Terminated

CHAPTER 4

RESULT OF CODE IMPLEMENTATION IN MATLAB

4.1 RESULTS

BASE STATION DEPLOYMENT

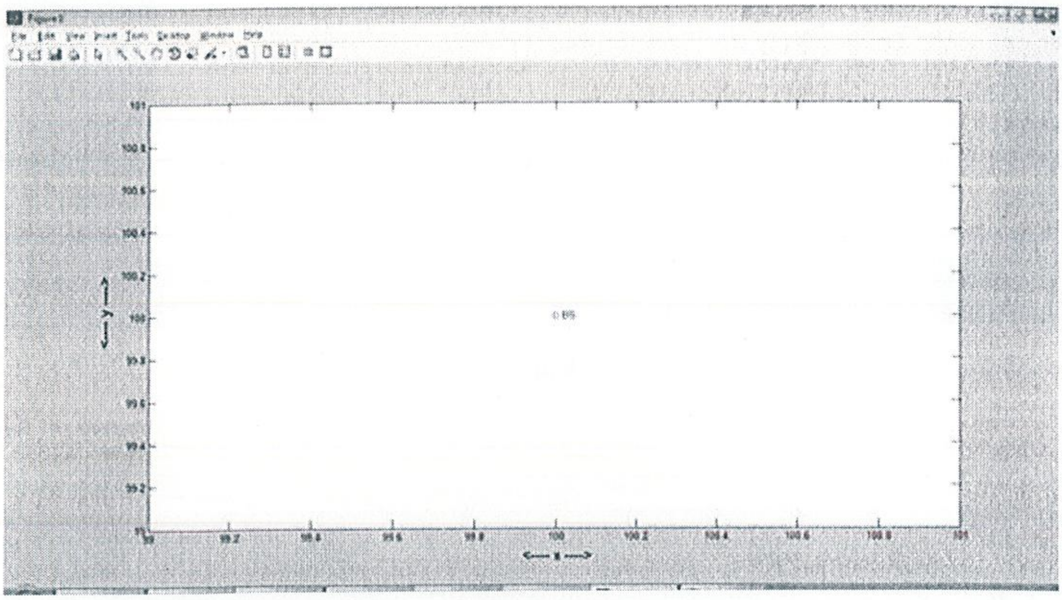


fig 4.1

$e1 = 0.0919$

$n1 = 818$

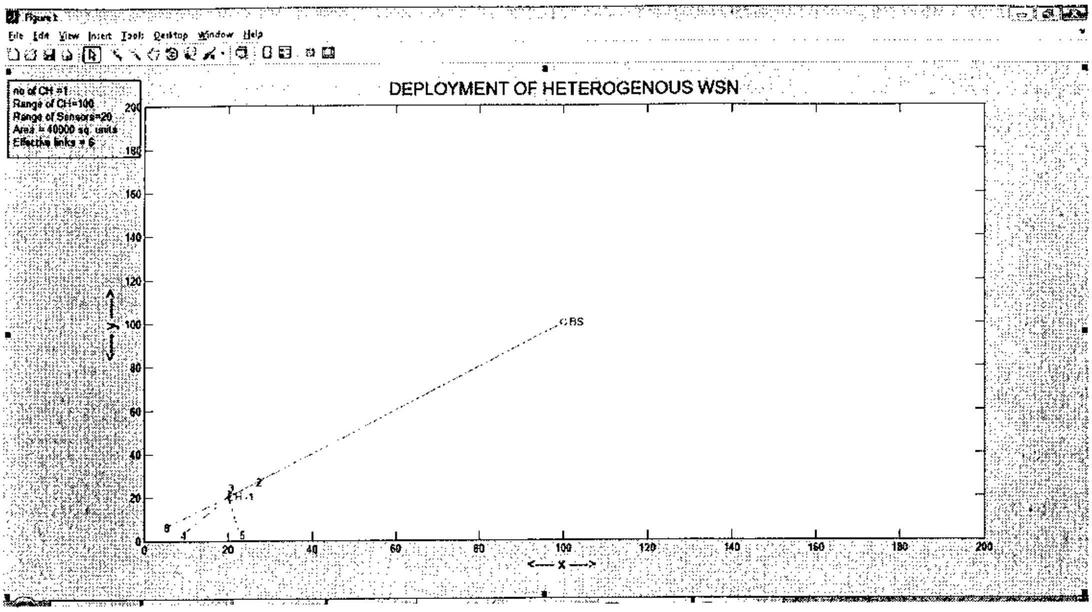


fig 4.2

$e2 = 0.0978$

$n2 = 3214$

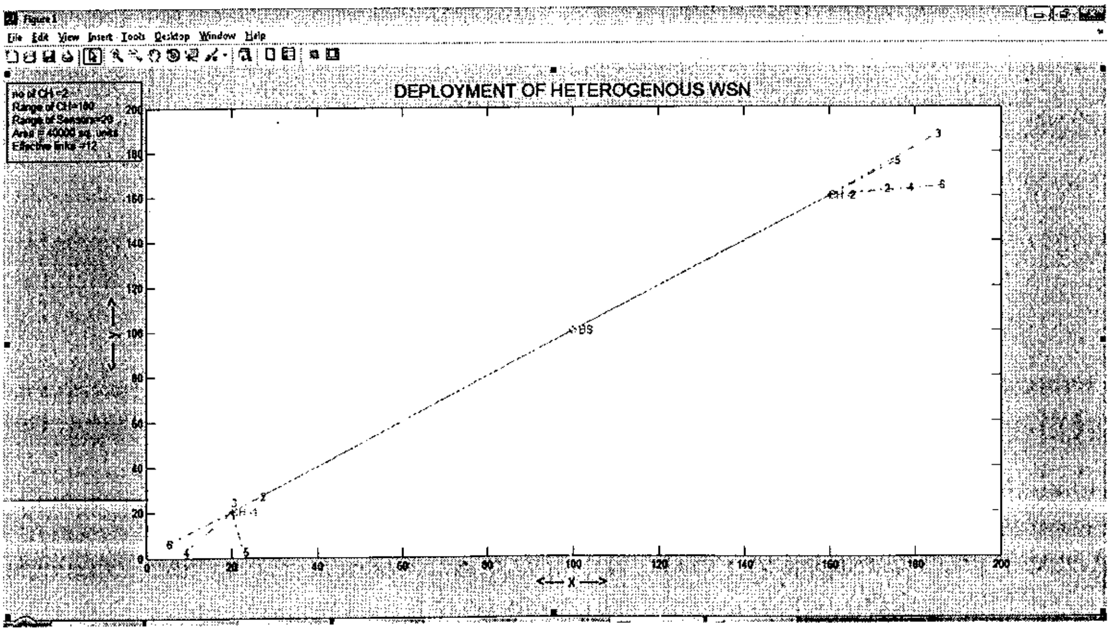


fig 4.3

e3 =   0.0988

n3 =   1433

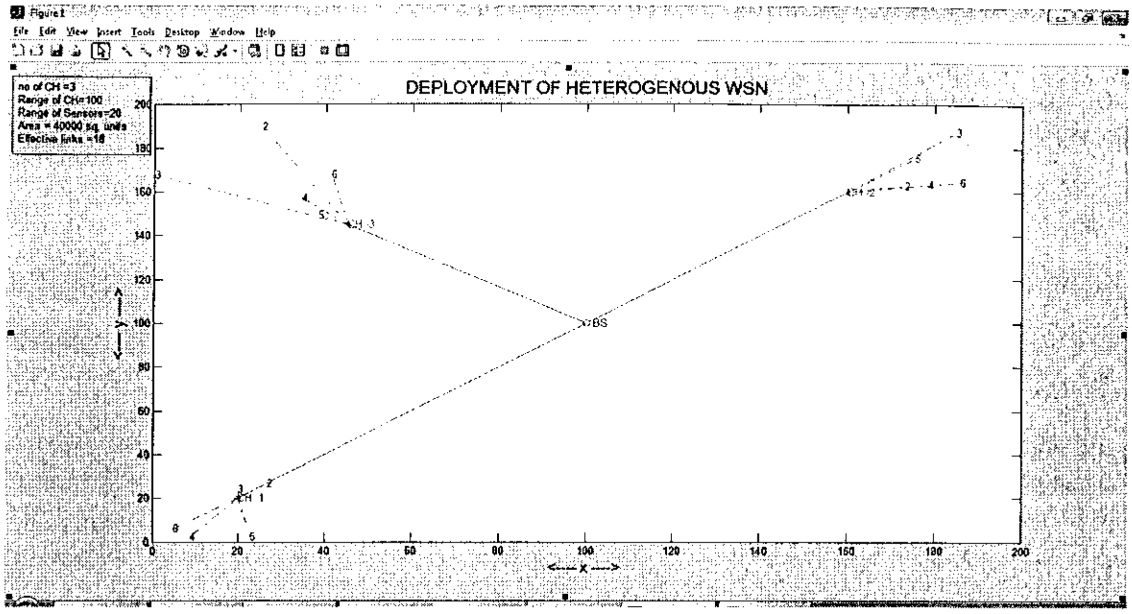


fig 4.4

e4 =   0.0910

n4 =   1070

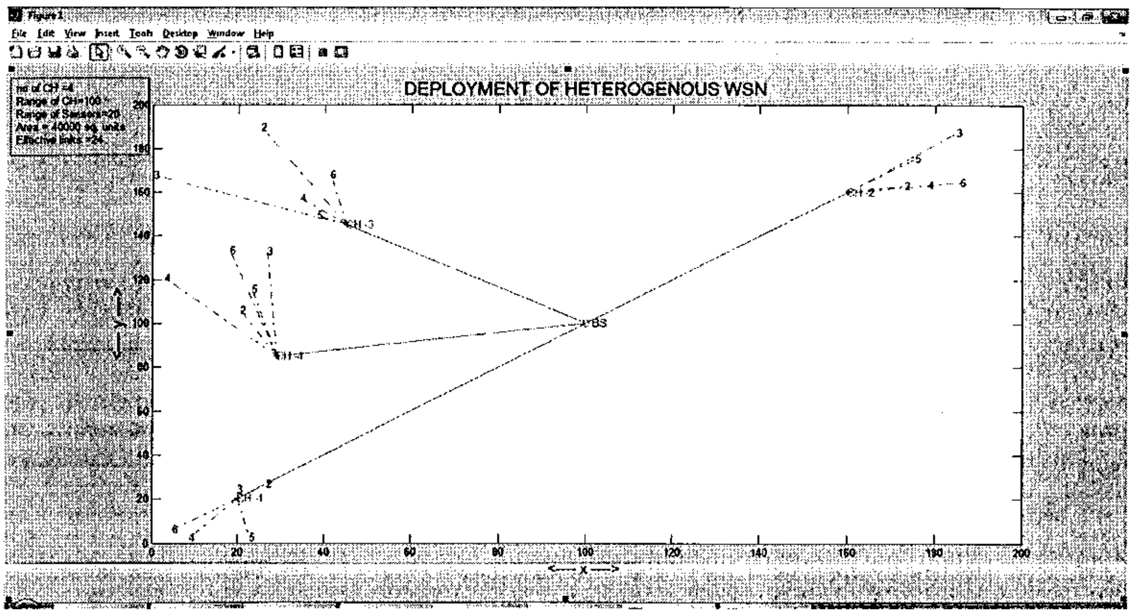


fig 4.5

e5 = 0.0963

n5 = 1133

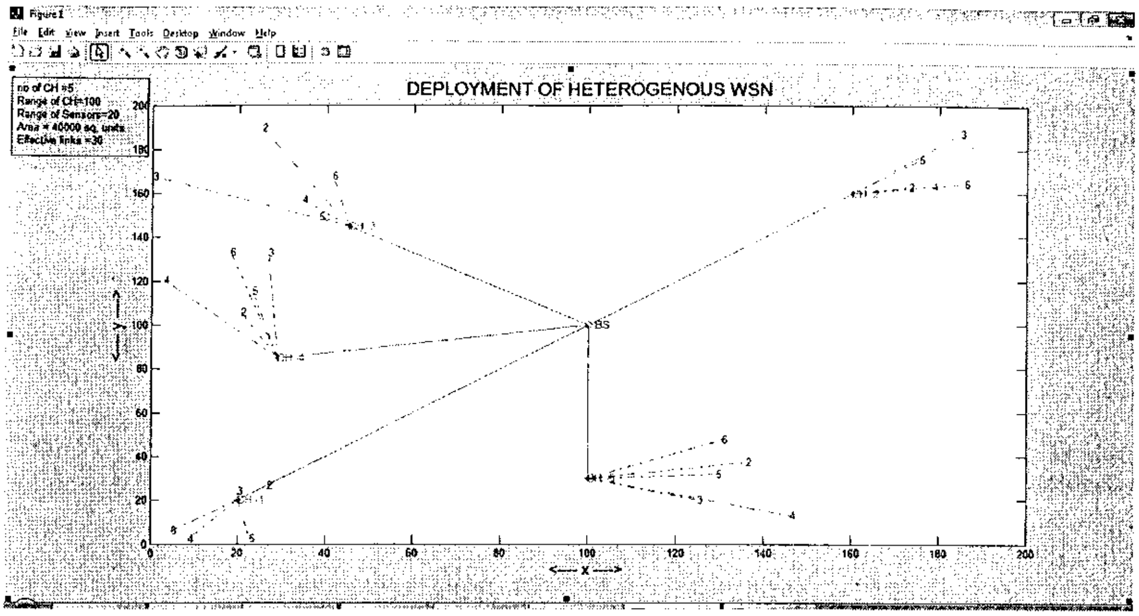


fig 4.6

e6 = 0.0981

n6 = 2702

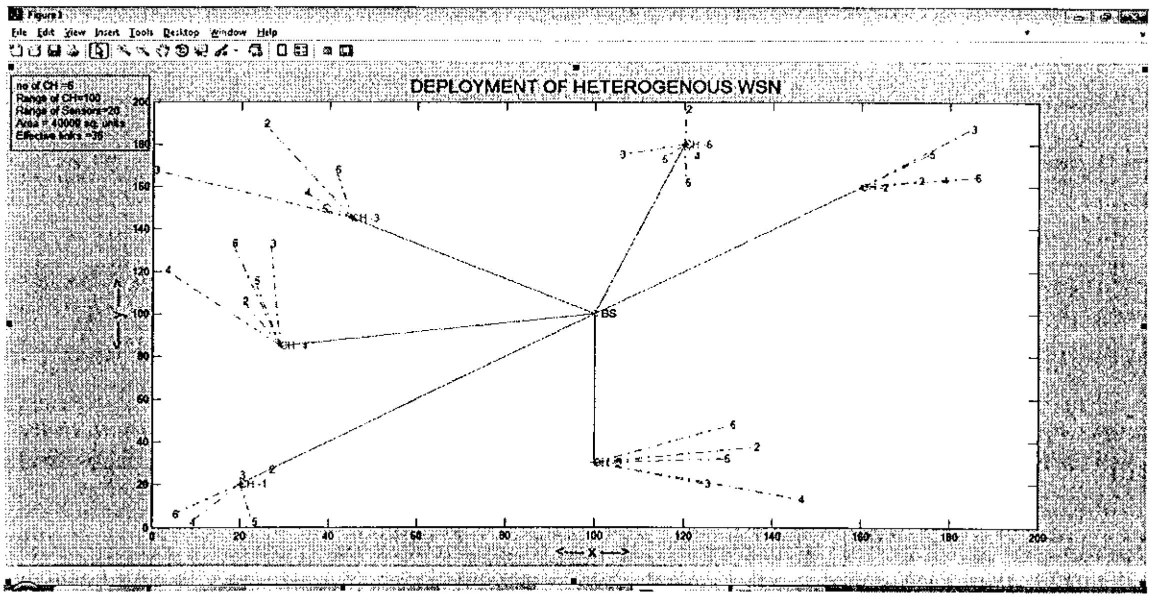


fig 4.7

e7 = 0.0958

n7 = 2131

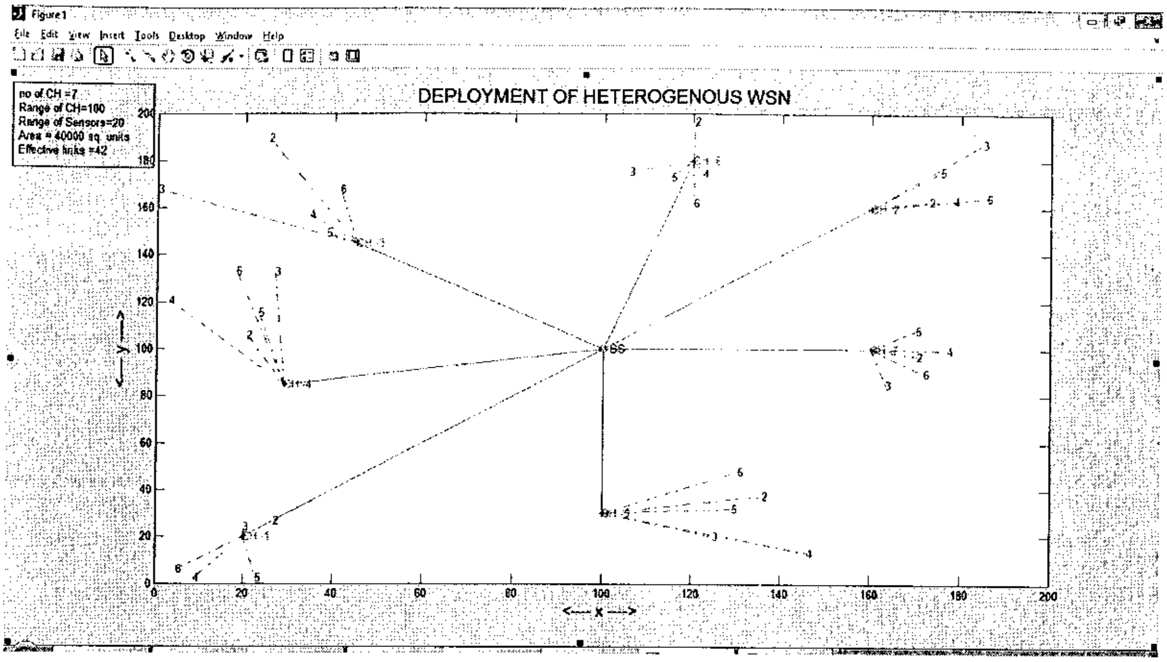


fig 4.8

e8 = 0.0978

n8 = 1555

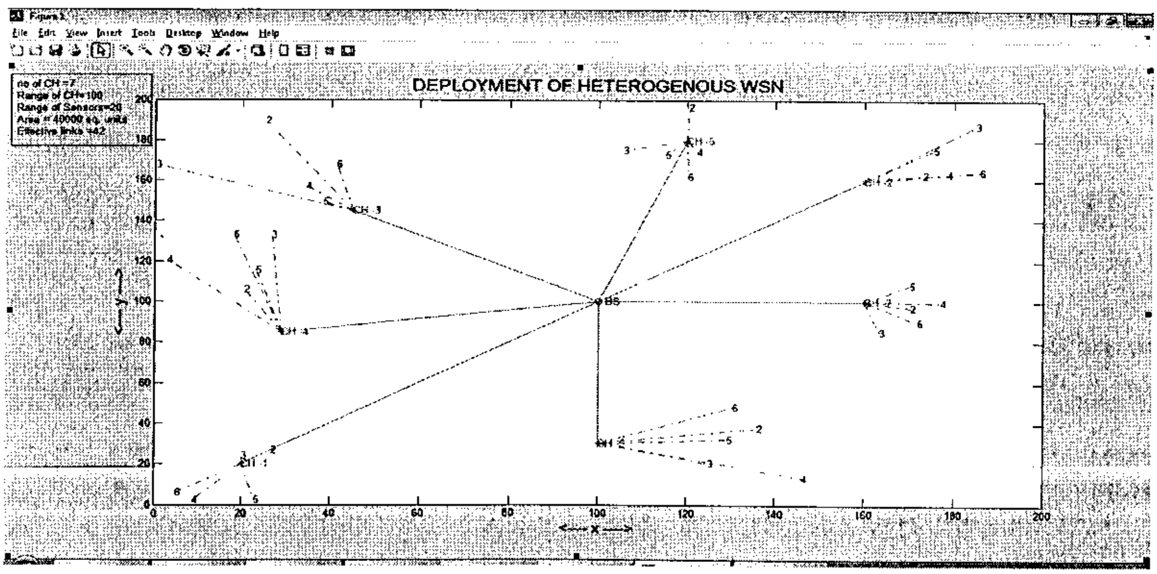


fig 4.9

CONCLUSION

In this project we have design the energy efficient routing protocol for heterogeneous wireless sensing networks for random nodes and fixed cluster head architecture. In future works we have design a system which have adaptive clustering means cluster nodes are mobile and not in the form of fixed deployment. We conclude that this type of architecture is more efficient than the single hop leach protocol because energy is directly proportional to square of distance, due to this fact multi-hop is more energy efficient than single hop.

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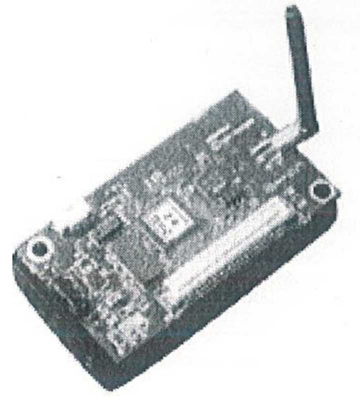
Crossbow

MICAz

WIRELESS MEASUREMENT SYSTEM

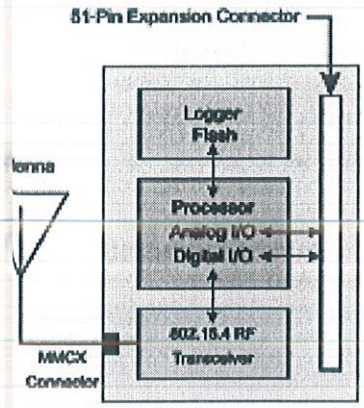


- 2.4 GHz IEEE 802.15.4, Tiny Wireless Measurement System
- Designed Specifically for Deeply Embedded Sensor Networks
- 250 kbps, High Data Rate Radio
- Wireless Communications with Every Node as Router Capability
- Expansion Connector for Light, Temperature, RH, Barometric Pressure, Acceleration/Seismic, Acoustic, Magnetic and other Crossbow Sensor Boards

Applications

- Indoor Building Monitoring and Security
- Acoustic, Video, Vibration and Other High Speed Sensor Data
- Large Scale Sensor Networks (1000+ Points)

ZigBee™ Alliance



MPR2400 Block Diagram

MICAz

The MICAz is a 2.4 GHz Mote module used for enabling low-power, wireless sensor networks.

Product features include:

- IEEE 802.15.4 compliant RF transceiver
- 2.4 to 2.48 GHz, a globally compatible ISM band
- Direct sequence spread spectrum radio which is resistant to RF interference and provides inherent data security
- 250 kbps data rate
- Supported by MoteWorks™ wireless sensor network platform for reliable, ad-hoc mesh networking
- Plug and play with Crossbow's sensor boards, data acquisition boards, gateways, and software

MoteWorks™ enables the development of custom sensor applications and is specifically optimized for low-power, battery-operated networks. MoteWorks is based on the open-source TinyOS operating system and provides reliable, ad-hoc mesh networking, over-the-air-programming capabilities, cross development tools, server middleware for enterprise network integration and client user interface for analysis and a configuration.

Processor & Radio Platform (MPR2400CA)

The MPR2400 is based on the Atmel ATmega128L. The ATmega128L is a low-power microcontroller which runs MoteWorks from its internal flash memory. A single processor board (MPR2400) can be configured to run your sensor application/processing and the network/radio communications stack simultaneously. The 51-pin expansion connector supports Analog Inputs, Digital I/O, I2C, SPI and UART interfaces. These interfaces make it easy to connect to a wide variety of external peripherals. The MICAz (MPR2400) IEEE 802.15.4 radio offers both high speed (250 kbps) and hardware security (AES-128).

Sensor Boards

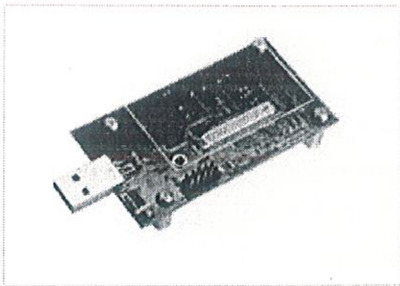
Crossbow offers a variety of sensor and data acquisition boards for the MICAz Mote. All of these boards connect to the MICAz via the standard 51-pin expansion connector. Custom sensor and data acquisition boards are also available. Please contact Crossbow for additional information.

Phone: 408.965.3300 • Fax: 408.324.4840 • E-mail: info@xbow.com • Web: www.xbow.com

Crossbow

Processor/Radio Board	MPR2400CA	Remarks
Processor Performance		
Program Flash Memory	128K bytes	
Measurement (Serial) Flash	512K bytes	> 100,000 Measurements
Configuration EEPROM	4K bytes	
Serial Communications	UART	0-3V transmission levels
Analog to Digital Converter	10 bit ADC	8 channel, 0-3V input
Other Interfaces	Digital I/O,I2C,SPI	
Current Draw	8 mA	Active mode
	< 15 μA	Sleep mode
RF Transceiver		
Frequency band[1]	2400 MHz to 2483.5 MHz	ISM band, programmable in 1 MHz steps
Transmit (TX) data rate	250 kbps	
RF power	-24 dBm to 0 dBm	
Receive Sensitivity	-90 dBm (min), -94 dBm (typ)	
Adjacent channel rejection	47 dB	+ 5 MHz channel spacing
	38 dB	- 5 MHz channel spacing
Outdoor Range	75 m to 100 m	1/2 wave dipole antenna, LOS
Indoor Range	20 m to 30 m	1/2 wave dipole antenna
Current Draw	19.7 mA	Receive mode
	11 mA	TX, -10 dBm
	14 mA	TX, -5 dBm
	17.4 mA	TX, 0 dBm
	20 μA	Idle mode, voltage regulator on
	1 μA	Sleep mode, voltage regulator off
Electromechanical		
Battery	2X AA batteries	Attached pack
External Power	2.7 V - 3.3 V	Molex connector provided
User Interface	3 LEDs	Red, green and yellow
Size (in)	2.25 x 1.25 x 0.25	Excluding battery pack
(mm)	58 x 32 x 7	Excluding battery pack
Weight (oz)	0.7	Excluding batteries
(grams)	18	Excluding batteries
Expansion Connector	51-pin	All major I/O signals

Notes
[1] 5 MHz steps for compliance with IEEE 802.15.4/D18-2003.
Specifications subject to change without notice



MIB520CB Mote Interface Board

Base Stations

A base station allows the aggregation of sensor network data onto a PC or other computer platform. Any MICAz Mote can function as a base station when it is connected to a standard PC interface or gateway board. The MIB510 or MIB520 provides a serial/USB interface for both programming and data communications. Crossbow also offers a stand-alone gateway solution, the MIB600 for TCP/IP-based Ethernet networks.

Ordering Information

Model	Description
MPR2400CA	2.4 GHz MICAz Processor/Radio Board
WSN-START2400CA	2.4 GHz MICAz Starter Kit
WSN-PRO2400CA	2.4 GHz MICAz Professional Kit

Document Part Number: 6020-0060-04 Rev A

APPENDIX B

MATLAB CODE

```
clear all;

close all;

clc;


x1=20; %input('Enter the BS  x position: ');

y1=20; %input('Enter the BS  y position: ');

CRx = 0;

CRy = 0;

L = 40;

sta = 0;

% deployment of 1st structure

s1 = randdeployment(x1,y1,CRx, CRy,L,sta);

[e1 n1] = energy(s1)

figure(1);

clf;


% Base station position

plot(100,100,'o');

text(100,100,'  BS');

a=1;

a = plott(s1,a);

hold on;

line([s1.x(1) 100], [s1.y(1) 100], 'Color','r','LineStyle', '-');

xlabel('<---- x ---->','FontSize',14);

ylabel('<---- y ---->','FontSize',14);

title('DEPLOYMENT OF HETEROGENOUS WSN','FontSize',16);


x1=160; %input('Enter the BS  x position: ');

y1=160; %input('Enter the BS  y position: ');

CRx = 160;

CRy = 160;

L = 30;
```

```
sta = sta + 1;
% deployment of 2nd structure
s2 = randdeployment(x1,y1,CRx, CRy,L,sta);
[e2 n2] = energy(s2)
a = plott(s2,a);
line([s2.x(1) 100], [s2.y(1) 100], 'Color','r','LineStyle', '-');

x1=45; %inpt('Enter the BS  x position: ');
y1=145; %input('Enter the BS  y position: ');
CRx = 0;
CRy =145;
L = 45;
sta = sta + 1;
% deployment of 3rd structure
s3 = randdeployment(x1,y1,CRx,CRy,L,sta);
[e3 n3] = energy(s3)
a = plott(s3,a);
line([s3.x(1) 100], [s3.y(1) 100], 'Color','r','LineStyle', '-');

x1=29; %input('Enter the BS  x position: ');
y1=85; %input('Enter the BS  y position: ');
CRx = 0;
CRy = 100;
L = 35;
sta = 0;
% deployment of 4th structure
s4 = randdeployment(x1,y1,CRx, CRy,L,sta);
[e4 n4] = energy(s4)
a = plott(s4,a);
line([s4.x(1) 100], [s4.y(1) 100], 'Color','r','LineStyle', '-');


x1=100; %input('Enter the BS  x position: ');
y1=30; %input('Enter the BS  y position: ');
```

```
CRx = 100;
CRy = 0;
L = 55;
sta = sta + 1;
% deployment of 5th structure
s5 = randdeployment(x1,y1,CRx, CRy,L,sta);
[e5 n5] = energy(s5)
a = plott(s5,a);
line([s5.x(1) 100], [s5.y(1) 100], 'Color','r','LineStyle', '-');

x1=120; %inpt('Enter the BS  x position: ');
y1=180; %input('Enter the BS  y position: ');
CRx = 100;
CRy =155;
L = 50;
sta = sta + 1;
% deployment of 6th structure
s6 = randdeployment(x1,y1,CRx,CRy,L,sta);
[e6 n6] = energy(s6)
a = plott(s6,a);
line([s6.x(1) 100], [s6.y(1) 100], 'Color','r','LineStyle', '-');


x1=160; %input('Enter the BS  x position: ');
y1=100; %input('Enter the BS  y position: ');
CRx = 160;
CRy = 80;
L = 40;
sta = sta + 1;
% deployment of 7th structure
s7 = randdeployment(x1,y1,CRx, CRy,L,sta);
[e7 n7] = energy(s7)
a = plott(s7,a);
line([s7.x(1) 100], [s7.y(1) 100], 'Color','r','LineStyle', '-');
```

```
x1=180; %inpt('Enter the BS  x position: ');
y1=40; %input('Enter the BS  y position: ');
CRx = 155;
CRy =0;
L = 45;
sta = sta + 1;
% deployment of 8th structure
s8 = randdeployment(x1,y1,CRx,CRy,L,sta);
[e8 n8] = energy(s8)
a = plott(s8,a);
line([s8.x(1) 100], [s8.y(1) 100], 'Color','r','LineStyle', '-');
```