“A FRAMEWORK FOR ENERGY EFFICIENT ROUTING PROTOCOL FOR HOMOGENEOUS WIRELESS SENSOR NETWORK USING SENSING RANGE”

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DECLARATION

We hereby declare that the work reported in the B. Tech report entitled "**A Framework For Energy Efficient Routing Protocol For Homogeneous Wireless Sensor Network Using Sensing Range"** submitted by "**Ms. Apeksha Chauhan, Ms. Tanvi Sharma and Mr. Raghove Bhargove"** at Jaypee University Of Information Technology, Waknaghat is an authentic record of our work carried out under the supervision of **Mr. Tapan Jain**. This work has not been submitted partially or wholly to any other university or institution for the award of this or any other degree or diploma.

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ABSTRACT

Wireless sensor networks are a collection of small, low cost and low power sensor nodes connected wirelessly with each other. The sensor nodes can be multifunctional or can be task specific. The senor nodes are associated with a fixed power, which enables a sensor node to perform tasks such as sensing, transmitting, processing etc. The power associated with every node is a very crucial determinant of the lifetime of the entire Wireless Sensor Network. Thus, energy optimization is very important and can help improve the lifetime a network tremendously. In our thesis we have proposed a similar concept which effectively enhances the network lifetime. We have used the concept of sensing range and removal redundant data. In our project we have taken a homogeneous network in which all the nodes have the same amount of energy associated with them and all the nodes are proactive that is the nodes always have data to sense. The energy computation of our model is based upon the first order radio model. Simulating our model in MATLAB and comparing the experimental results with other existing models such as Direct Transmission Model, LEACH and Minimum Transmission Energy Model, proved that our proposed model greatly enhanced the network lifetime.

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ACRONYMS

MEMS	Micro Electro Mechanical Systems
WSN	Wireless Sensor Network
CH	Cluster Head
TDMA	Time Division Multiple Access
ICU	Integrated Circuit Units
ADC	Analog to Digital Converter
WLAN	Wireless Local Area Network
LEACH	Low Energy Adaptive Clustering Hierarchy
RF	Radio Frequency
GEAR	Geographic and Energy Aware Routing
GAF	Geographic Adaptive Fidelity
BS	Base Station
MTE	Minimum Transmission Energy
CSMA	Carrier Sense Multiple Access
MAC	Medium Access Control
SNR	Signal to Noise Ratio
PM	Proposed Model
DTM	Direct Transmission Model

INDEX WORDS

Clustering, Homogeneous, Heterogeneous, Sensing Range, Transmission Range, Data Aggregation, Routing

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recent advances in wireless communications, micro-electro-mechanical systems (MEMS) technology have enabled the development of tiny low-cost and low power multitasking sensor nodes that are small in size and communicate untethered in short distances. These multifunctional tiny sensor nodes, which have basic components of sensing, data processing, and communicating, leverage the idea of sensor networks based on collaborative effort of a large number of nodes.

Advanced Sensor networks are significantly improved networks over the traditional networks and these can be deployed in following two ways:

- Sensors can be deployed away from the phenomenon. In this deployment sensors which can clearly distinguish target from the environmental noise are placed away from the target.

- Sensors which only sense the phenomenon can be deployed and topology of these tiny sensors is decided carefully. These sensors transmit data using TDMA schedule decided by cluster head nodes to these cluster heads where data aggregation and fusion takes place.

A WSN is made up of a large number (sometimes order of 10^6) of sensor nodes, which are densely deployed either inside the phenomenon or very close to it.

The position of sensor nodes is random and not pre-determined and due to this random deployment access to inaccessible terrains where humans can't reach directly or disaster relief operations becomes possible. This implies Wireless Sensor Network algorithms and protocols must empower network with some self-organising capabilities. One very unique feature of sensor networks is the cooperative effort of sensor nodes. Sensor nodes have an-board processor. Instead of sending the raw data received from sensor nodes directly to the nodes doing data fusion, sensor nodes use their processing and computational abilities to locally process data, carry out simple computations and transmit only the required and processed data. In technical terms this is known as data aggregation. These data aggregation and data fusion algorithms remove large overheads over the sensor nodes and enhance the life of the sensor networks which is a great field of research these days.

The above described features ensure a wide range of applications for Wireless Sensor Networks. These application areas are health, military, and security etc. For example, a patient in ICU can be monitored by team of doctors indirectly outside the ICU. Some psychological problems are better understood when doctors are not in direct contact with patients so that patient can be there in as natural as possible environment and patients also have more convenience with this. With this doctors have better understanding of patients' current condition. These sensor networks can also be used to detect foreign polluting chemical agents in the air and the water. They can help to identify the concentration, type, and location of pollutants.

Fig. 1.1 Wireless Sensor Network Device

WSNs may consist of a lot of different types of sensors such as seismic, magnetic, thermal, optical, infrared and acoustic, able to examine a wide range of ambient circumstances. Though each individual sensor may have cruel resource constraint in terms of power, memory, communication and computation capabilities; huge number of them may cooperatively monitor the physical world, distribute information upon critical environmental actions and process the information on the fly. The issues of network lifespan and optimum energy usage are tremendously essential in WSNs due to the limited power source available with them. System should provide energy efficient algorithms in routing as well as in other energy consuming processes so that network lifespan and hence reliability of network can be increased. We envision that, as computers are today basic necessity in every aspect of humans, in future, wireless sensor networks will be an integral part of our lives and will find applications in every basic field related to us.

1.2 Motivation

WSNs are composed of huge number of sensor nodes, which are densely deployed either within the phenomenon or in the close proximity of the phenomenon. All the sensor nodes sense this phenomenon and transmit the information to the base station using network specific methodology for transceiving operation.

All these operations consume particular amount of energy. The current area of WSNs has brought various new challenges to developers of system protocols. One of these challenges consists of optimum energy usage by the network to enhance its lifespan and hence the reliability. In WSNs there are many issues which are to be taken care during the deployment of any network like network coverage, data aggregation, data fusion. There's a lot of work done in these fields already. Among all these issues optimising energy usage is the biggest issue in WSNs. So our project focuses on making a framework for energy efficient routing protocol for homogeneous WSNs using sensing range.

1.3 Objective (Problem Statement)

Wireless Micro Sensor Networks have limited battery power with them, hence optimum energy usage is needed. The objective of our project is to design an energy efficient multi-hop wireless sensor network. To achieve this we propose the concept of merging. In merging, two nodes can work in sleep and active mode if the distance between them is less than their sensing range. Whichever node will be working in active mode will have slightly more energy than passive node. Wireless sensor networks are very dense networks and nodes are very densely deployed therefore the probability to merge the nodes increases greatly and so does the energy efficiency.

Designing of an energy efficient routing protocol is important since battery power is limited and irreplaceable. The energy is utilized for various processes such as transmission, processing of data etc. The rate at which energy consumed in all these processes determine the lifetime of network. So to increase the lifetime of network we are working on energy efficiency of network.

1.4 Software used

We used MATLAB (Matrix Laboratory) 2012 for our network simulations. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is a numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the Mu PAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

In 2004, MATLAB had around one million users across industry and academic. MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises. We simulated our network on MATLAB and compared our results with existing models.

1.5 Outline of Dissertation

As we have seen in CHAPTER 1 we have introduced Wireless Sensor Networks and discussed our motivation behind this thesis, problem statement and basics of Wireless Sensor Networks.

In CHAPTER 2 we will discuss in some more detail about Wireless Sensor Networks and will try to build some base knowledge for these networks by discussing Wireless Sensor Network Architecture, Factors influencing architectural design which will enlighten the reader about architecture of these networks. We will try to understand some characteristics of Wireless Sensor Networks and will also see different types of these networks mainly Homogeneous and Heterogeneous. We will also discuss about some operational modes in which these networks and nodes can work and about various types of protocols. All these will increase our understanding about Wireless Sensor Networks.

In CHAPTER 3 we will introduce some of the existing transmission models and will explain about all these models. In addition we will bring out some differences in existing models with respect to each other and will explain LEACH in detail.

In CHAPTER 4 which is penultimate chapter we will be talking about our proposed work, and will be explaining in detail about our proposed model, assumptions taken in our model and proposed algorithm for our model to work. Finally as flow charts is very concise form of understanding any algorithm, we will try to understand whole algorithm in terms of flow chart.

In CHAPTER 5 which is last and concluding chapter of this thesis we will be mentioning our results which we obtained during our simulations and will compare our results with existing models in our field of research.

In CHAPTER 6 we will be concluding this thesis and will be throwing some light on the future options open for this field of research.

CHAPTER 2

THEORETICAL BACKGROUND

2.1 WSN Architecture

The sensor nodes are usually scattered in a sensor field as shown in Figure 2.1. Each of these scattered sensor nodes has the capability to collect data and route data back to the sink/gateway and the end-users. Collected data are routed back to the user by a multi-hop infrastructure less architecture through the sink as shown in Figure 2.1. The sink may communicate with the task manager/end-user via the Internet or satellite or any type of wireless network (like Wi-Fi, mesh networks, cellular systems, WiMAX, etc.), or without any of these networks where the sink can be directly connected to the end-users. Note that there may be multiple sinks/gateways and multiple end-users in the architecture shown in Figure 2.1. In WSNs, the sensor nodes have the dual functionality of being both data originators and data routers. Hence, communication is performed for two reasons:

- **Source function:** Source nodes having information of event perform communication functionalities in order to transmit their packets to the sink.
- **Router function:** Sensor nodes also participate in forwarding the packets received from other nodes to the next destination in the multi-hop path to the sink.

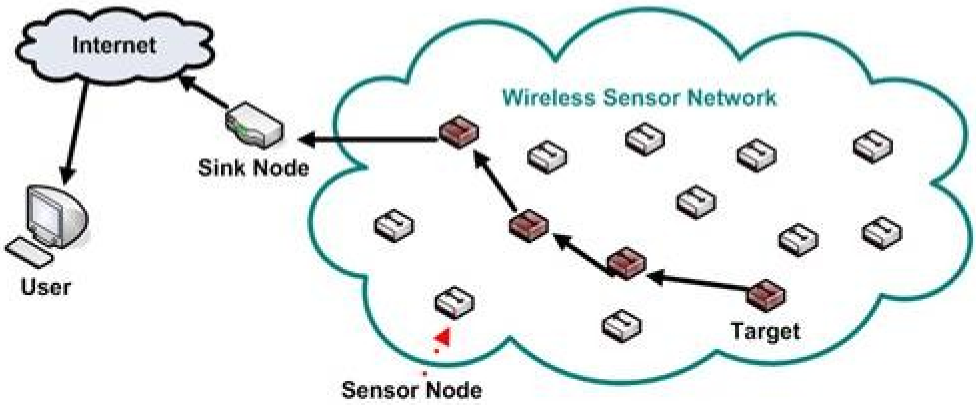


Fig.2.1 WSN Architecture

2.2 Factors Influencing Architectural Design

In this sub-section, we intend to describe the design factors of overall wireless sensor networks communications architecture as well as the design factors of protocols and algorithms for wireless sensor networks (WSNs). Many design factors have been addressed by many researchers in this field. These design factors are surveyed below. These factors serve as hints or guidelines to design a protocol or algorithm for WSNs.

2.2.1 Reliability

Reliability or fault tolerance or of a sensor node is the ability to maintain the sensor network functionalities without any interruption due to sensor node failure. Sensor node may fail due to lack of battery power, any physical damage to nodes, communications problem, inactivity (a node becomes suspended), or any external interference. Reliability is modelled using the Poisson distribution to capture the probability of not having a failure within the

Time interval (0, t):

$$R_k(t) = e^{-\lambda.kt}$$

Where k: is the failure rate of sensor node, t is the time period and λ is a constant.

2.2.2 Density and Network Size/Scalability

Hundreds, thousands or millions of sensor nodes may be deployed to study a phenomenon of interest to users. The density of these nodes affects the degree of coverage area of interest. The networks size affects reliability, accuracy, and data processing algorithms. The density can range from a fewer sensor nodes to a hundred in a region that can be less than 10m in diameter. The density is calculated as in:

$$\mu(R) = N\pi R^2 /A$$

Where N is the scattered sensor nodes in region A, and R is the radio transmission range. Basically, this $\mu(R)$ gives the number of nodes within the transmission radius of each node in region A.

2.2.3 Sensor Network Topology

The topology of a network affects many of its characteristics like latency, capacity, and robustness. Also, the complexity of data routing and processing depends on the network topology. Densely deploying thousands of sensor nodes in sensor field requires careful handling of network topology maintenance. Four phases related to topology maintenance and changes (e.g., malfunctioning of some sensor nodes) are, Pre deployment, Deployment phase, Post deployment phase, and Redeployment of additional nodes phase.

2.2.4 Energy Consumption

One of the components of sensor nodes is the power source which is limited enough. A sensor node is battery-operated. Hence life time of a sensor node depends strongly on the battery life time, especially where no power source replenishment is possible in some applications scenarios. Since the main objectives of sensor nodes are sensing/collecting events, data processing, and data transmission through routing; then the power resource can be divided among these three operations (sensing, computation, and communications). On the other hand; life time of a sensor node plays a key role on energy efficiency and robustness of sensor node. Hence many researches are focusing on designing power-aware protocols and algorithms for wireless sensor networks with the goal of minimization of energy expenditure.

2.2.5 Hardware Constraints

Sensor node consists of four main components: a sensing units, processing unit, transmission unit, and power unit. They may also have application-dependent additional components such as position/location finding systems, power generator, and a mobilizer. Sensors are usually composed of two components:

- **Sensors and ADC (Analog to Digital Converter)**

The Analog signals produced by sensors based on the observed phenomenon are converted by ADC to digital signal and fed into the processing unit to be processed. Processing unit, generally associated with storage unit, manages the procedures that make the sensor node collaborate with other nodes to perform the assigned sensing tasks.

- **Transmission unit that connects the sensor node to the network**

Power unit may be supported by a power scavenging such as solar cells. Since most of the sensor network routing techniques and sensing tasks require knowledge of location with high accuracy, thus it is common that a sensor node has a position/ location finding system. Sometimes, a mobilizer is needed to move sensor node to carry out the assigned tasks. Hence, the size of sensor node in of a great design issue.

2.2.6 Data Aggregation/Data Fusion

It is the task of reducing data size by summarizing the data into a set of meaningful information via computation while data are propagating through the wireless sensor network (in this context). As sensor networks are made up of large number of sensor nodes this can easily congest the network and flooding it with information. Hence a solution to data congestion in sensor networks is to use computation to aggregate or fuse data within WSN, then transmit only the aggregated data to the controller. Many approaches within the context of WSNs are proposed to facilitate data aggregation, also known as data fusion, such as diffusion algorithms which assume that homogeneous data propagate to destination throughout the network by transmitting data from one node to another, then these data may be aggregated using diffusion algorithms, streaming queries are based on SQL extension for continuous querying, and event algebra which assists in composing simple events into composite ones with the help of event graph.

2.2.7 Transmission Media

In a multi-hop sensor network, a wireless medium is used to link nodes for communications goal. These links can be formed by radio (e.g., Bluetooth compatible 2.4 GHz transceiver), infrared which is license free and robust to interference from electrical devices, and Optical media.

2.2.8 Security

Security aspects in WSNs have been focused on the centralized communications approaches. Some of the threats to a WSN are categorized as follows: Passive Information Gathering, False Node, Node Outage and Supervision of a Node, Node Malfunction, Message Corruption, Denial of Service, and Traffic Analysis. There is a need to develop distributed security approaches for wireless sensor network.

2.2.9 Self-Configuration

It is essential for wireless sensor network to be self-organize since the densely deployed sensor nodes in a sensor field may fail due to many reasons (e.g., lack of energy, physical destruction, environment interference, communications problem, inactivity, etc.) and new nodes may join the network. On the other hand sensor nodes work unattended in a dynamic environment so they need to be in self-configuration to establish a topology that supports communications under severe energy constraints. It is worthy mention that self-configuration in WSN is an essential factor to maintain a WSN functions properly and serve its purpose.

2.2.10 Network dynamics

In many applications, the movement of sensor nodes or the base station (sink) is essential. This means that sensor nodes are moving nodes (i.e., not stationary as assumed by many of network architectures). This has arisen the routing stability issues as well as energy, bandwidth, etc. Moreover, the specific sensed phenomenon may be either dynamic (e.g., target detection/ tracking applications) or stationary (e.g., forest monitoring) depending on the applications.

2.2.11 Quality of Service

For some applications, data delivery within a bounded latency (i.e., time constrained applications) is of great importance otherwise, the sensed data that is delivered after certain latency will be useless. In other applications (e.g., not time-constrained applications), the conservation of power is more important than the quality of the sent data. Hence there is a trade-off between the quality of service/the quality of data sent and the energy conservations or consumption depending on the applications.

2.2.12 Coverage

The sensor nodes' view of the environment that it is situated in is limited both in range and in accuracy. This means the ability of sensor nodes to cover physical area of the environment is limited.

2.2.13 Connectivity

A permanent connection between any two individual sensor nodes that are densely deployed in a sensor network defines the network connectivity. The connectivity is of great importance, since it influences communications protocols' design and data dissemination techniques. Also, it is worth mentioning that connectivity of sensor network may not prevent the network topology from being variable and the network size from reduction as a result of the death or failure of some sensor nodes.

2.3 Operation Phase of Wireless Sensor Network

A typical wireless sensor network operates in five phases which are pre-deployment phase, deployment phase, post-deployment phase, operation phase, and post-operation phase.

1. In pre-deployment phase, a site survey is conducted to evaluate deployment environment and its conditions to select a suitable deployment mechanism.
2. In deployment phase, sensors are randomly deployed over a target region. The deployment can be done by throwing nodes from planes, delivering through shell, rocket or missile, throwing them using catapult, placing in factory or placing each mode one by one using human robot.
3. In post- deployment phase, the sensor network operators need to identify or estimate the location of sensors to access the coverage.
4. In operation phase, normal monitoring tasks take place and sensors generate data. In this phase topology of network may change and this change may occur due to positioning of nodes, limited energy with nodes, reachability issues, malfunctioning or task details etc.
5. The post-operation involves shutting down and preserving the sensors for future operations or destroying the sensor network.

Sensor nodes can be used for non-stop sensing, occurrence detection as well as recognition, position sensing and control of actuators. The nodes are deployed either within the phenomenon or incredibly close to it and can function unattended. Therefore they work unattended in most of the geographic areas. They may be working in busy intersections, in interior of large machinery, at the bottom of ocean, inside a twister, at surface of ocean during tornado, in a biologically or chemically contaminated fields, in a battlefield beyond enemy lines, in a home or large building, in vehicles, in the drain or river moving with current etc.. They can use their processing abilities to nearby bear out simple computations and transmit only required and moderately processed data. They may be structured into clusters or work together to complete a task that is issued by the users. In addition, position of these nodes do not need to be predefined. This feature allows their random deployment in inaccessible terrains . The WSN provides an intelligent platform to gather data and process it without any human intervention. WSNs are battery driven networks and as they are deployed in some inaccessible terrains battery is usually un-replaceable. Moreover they are of very small size so they cannot carry large battery and they are bound to have on limited energy with them. For example, total energy with a mote is only 1J. Since this is the only energy which is supplying power to a node, it decides its lifetime. So a great deal of research is going on to increase lifespan of WSN by optimizing energy usage in various processes of a WSN and it is also a significant issue at all layers of WSN.

The position of sensor node need not to be engineered or pre-determined. This allows deployment in unreachable terrains or calamity relief operations. On the other hand, this random deployment requires the improvement of self-organizing protocols for the communication protocol stack. In addition to the assignment of nodes, the density in the network is also oppressed in WSN protocols. Due to the short transmission ranges, large numbers of sensor nodes are densely deployed and neighbouring nodes may be very close to each other. Hence multi-hop communication is exploited in communications between nodes since it leads to less power consumption than the traditional single hop communication.

2.4 Wireless Sensor Network Characteristics

A WSN in itself is different from other various kinds of networks like Bluetooth network, WLAN (Wireless local area network), Cellular network and other ad-hoc networks. Compared to all these above mentioned networks, a WSN has large number of nodes in a network, application data rate is much lower and distance between the adjacent nodes is much short. Due to all these reasons power consumption in WSN must be minimised. Table 2.1 compares characteristics of WSNs and ad hoc networks. WSN is has a large number of nodes in order of 10^6, so the cost of each sensor node should be low so that whole network is economical. Also the smaller size of the noes makes it possible for a sensor node to be rooted in its surroundings it is in. A WSN may have a lot of redundant data so the gathered information first needs to be processed using data aggregation algorithms to save the energy by decreasing number of transmissions and receptions and hence increase the lifetime of network.

Table 2.1 Comparison between Wireless Sensor Network and Ad-Hoc Networks

Wireless Sensor Networks		Ad Hoc Networks	
i.	The nodes are densely deployed in WSN	i.	Number of nodes are less than WSN
ii.	Nodes are very densely deployed	ii.	Deployment is less dense as compare to WSNs
iii.	Sensor nodes are more prone to failure ,hence less reliable	iii.	Reliability is more in ad hoc networks
iv.	Topology of sensor nodes changes very frequently	iv.	Topology of ad hoc network nodes(stations) is more stable than WSNs
v.	Sensor nodes mostly broadcast the information	v.	Most of the ad hoc networks use point to point communication.
vi.	Sensor nodes have limited power, memory and computational capacity	vi.	Nodes (stations) in ad hoc networks can be recharged, have higher capacity
vii.	As number of sensor nodes is very large ,global IDs can't be given to nodes	vii.	As number of stations is not much in ad hoc networks, each station can be provided with global ID

2.5 Homogeneous and Heterogeneous Wireless Sensor Networks

2.5.1 Homogeneous networks

All the sensor nodes are identical in terms of battery power and hardware complexity. With purely static clustering (cluster heads once elected, remain CH for lifetime of network) in a homogeneous network, it is evident that the cluster head will be overloaded with the long range transmission to remote base station, and extra processing for data aggregation and protocol coordination. As a result the CH expires before other nodes. However it is desirable to ensure that all the nodes run out of their battery at about same time, so that a very little residual energy is wasted when the network dies. One way to ensure this is to rotate the role of all CHs periodically (i.e. change cluster heads after some time) over all the nodes as proposed in LEACH.

However a limitation of using a homogeneous network and role rotation is that all the nodes should be capable of acting as CH, and hence should possess all the capabilities to be the cluster head.

2.5.2 Heterogeneous networks

In heterogeneous network, two or more different types of nodes with different battery power and functionality are used. As more complex hardware and the extra battery power can be embedded in few CH, the hardware cost of the rest of the network can be reduced. But fixing the CH mean that no longer role rotation is possible.

When the sensor nodes use single hop to reach the CH, the nodes that are the farthest from the CH always spend more energy than the ones that are closer to CH. On the other hand when the nodes use multi-hop to reach the CH, the nodes that are the closest to the CH have the highest energy burden due to relaying. Consequently there always exists a non-uniform energy drainage pattern in the network.

Thus there are two desirable characteristics of a sensor network that is lower hardware cost and uniform energy drainage pattern. Due to different hardware complexity of each node heterogeneous networks achieve the former, the homogeneous networks achieve the latter.

2.6 Basic Structure of Sensor Node

Basically there are four major components of wireless sensor nodes as shown in Figure 2.3. These are:
A Sensing Unit, A Processing Unit, A Transceiver Unit and A Power Unit. Some other components which are application dependent are also there in a sensor node .We will describe each component in detail.

2.6.1 Sensing Unit

Sensing units are usually composed of two subunits: sensors and analog to digital converters (ADCs). The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and are further fed into the processing unit.

2.6.2 Processing Unit

The processing unit, which normally has low storage capacity, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks.

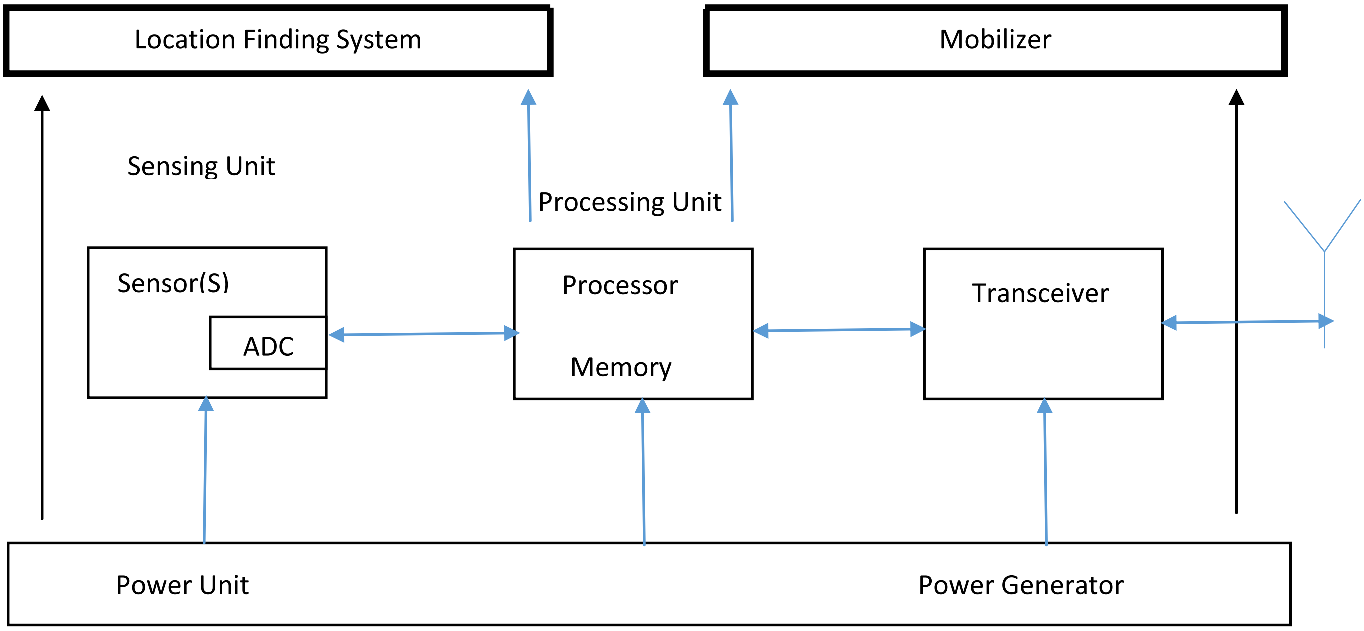


Fig.2.2 General Architecture of Wireless Sensor Node

2.6.3 Transceiver Unit

Whole communication process between any two sensor networks or within the sensor network is carried by a transceiver unit. This unit implements necessary procedures to covert bits to be transmitted into radio frequency (RF) waves and recover them at other hand.

2.6.4 Power Unit

One of the most important components of a sensor node is the power unit. These units are supported by some sources which can generate power indirectly like solar cells.

2.6.5 Location Finding System

Most of the sensor network routing techniques and sensing tasks require the knowledge of location with high accuracy so commonly sensor node has a location finding system. This system may consist of GPS module for a high end sensor node or may be a software module that implements the localization algorithms that provide location information through distributed calculations

2.6.6 Mobilizer

Sometimes it is needed to move the sensor nodes depending upon the assigned tasks. This unit moves the sensor nodes and this mobility support requires extensive energy resources and should be provided extensively.

2.6.7 Power Generator

Mostly power is used in the sensor nodes, it is provided with extra power generation unit so that power can be provided to the sensor nodes for applications needing longer life time.

Among all the units described above transceiver unit is the most expensive one in terms of energy usage as it connects whole network to rest of network.

2.7 Clustering

Grouping of the nodes falling within the certain transmission range of a particular node is known as clustering. Each cluster has a node with respect to which distance of all the nodes is measured often referred as, cluster-head (CH). Many clustering algorithms have been proposed and the main motive of all the proposed algorithms is to generate stable clusters and route stability. Clustering doesn't bother much about Wireless Sensor Networks (WSN's) goals like network coverage and lifetime of networks. CHs in a network can be elected by the sensors in the cluster or these can be pre assigned by the network designer. Cluster head can also be elected on the basis of resources it has, for example energy associated with a node. Other parameters which help in electing CHs are, how many cluster heads can be there in a networks, how many times a particular node has been a cluster head etc.

But there are some issues with clustering. First, there should be optimum number of clusters, so that performance of the network can be optimized. Second, how many numbers of nodes can be included in one cluster. There should be a quantization of parameters for selecting a cluster head. Third, if the network is heterogeneous then, user can give high energy to some nodes and those nodes have maximum probability of acting as cluster heads and other nodes will act as normal nodes. So the selection of CH's also depends on whether your network is homogeneous or heterogeneous. Every cluster has cluster head and member nodes. Thus, clustering is a two tier structure comprising of the cluster heads which form the upper hierarchy and member nodes which form the lower hierarchy. Clustering is important because it makes the network more efficient through the techniques of data aggregation.

Along with the network scalability there are numerous advantages of clustering. Since it limits the scope of inter-cluster interactions to CH's, it conserves the communication bandwidth and avoids redundant exchange of messages among sensor nodes. Clustering also stabilizes the network topology and thus cuts on topology maintenance overhead. Sensor nodes will only be concerned with connection with CH, so the change in a CH level tier will not affect the sensor nodes. CH's can further implement optimized management strategies which will prolong the battery life. CH's also schedule sensor nodes in the scheduling phase following TDMA techniques following which sensor nodes can work in sleep and active mode and hence can conserve energy of the network. CH in a cluster collects data from the sensor nodes and coverts it into small sets of meaningful information using data aggregation techniques.

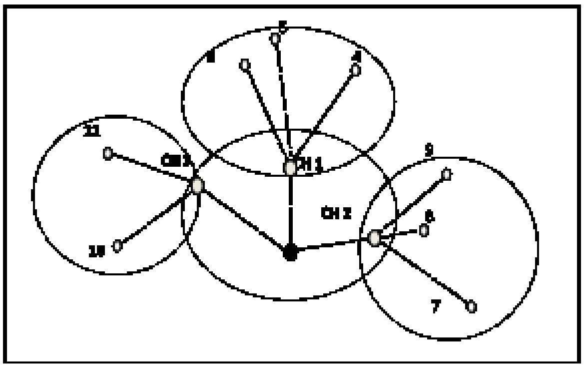


Fig.2.3 Shown are 3 clusters with cluster heads CH1, CH2, CH3

2.8 Protocols

Depending upon the network structure all the routing protocols can be broadly classified in three broad categories:

- Flat Routing
- Hierarchical Routing
- Location based Routing

2.8.1 Flat Routing

In flat routing protocol information is distributed to all the nodes that can be reached or can receive information in the network. The aim of this protocol is not to organize the network or maintain the traffic, but to transmit information through hoping and finding the best route to reach the destination. This type of routing is used mainly in flat structures which contain a huge number of sensor nodes. In flat routing protocol every node has a separate entry in the routing table. All the nodes in the network are equal and behave the same task of information gathering and sensing data. As global IDS cannot be assigned hence this is a data centric approach in which every node is considered as a potential receiver. In this protocol a node sends query in a particular region and waits for a response from that region. SPIN (sensor protocol for information and negotiation) is an example of flat routing protocols. Some other flat routing protocols are Directed Diffusion, Rumor Routing, Minimum Cost Forwarding algorithm, Gradient Based routing, Information Driven Sensor Query and Constrained Anisotropic Diffusion Routing, Energy Aware routing, Routing protocol with Random Walks(data centric routing).

2.8.2 Hierarchical Routing

This routing protocol is used in hierarchical structures like internet. In Hierarchical routing different clusters are formed and then a cluster head is chosen depending on the energy of the nodes. The higher energy nodes are used for data processing and data transmission whereas the lower energy nodes are used for sensing data in the close proximity region. This protocol is efficient in terms of scalability as it reduces the number of entries in the routing table. This protocol reduces the load on nodes. Hierarchical Routing has two layers, in the first layer cluster head is selected and in the second layer routing is done. Hierarchical Routing reduces the energy consumption in a cluster and reduces the transmitted message by data aggregation and fusion to the base station. LEACH (low energy adaptive clustering hierarchy) is a form of hierarchical routing protocol.

2.8.3 Location Based Routing

In location based routing the nodes are identified by their location and the distance between the neighbouring nodes can be determined by the incoming signal strength. Location of a node can also be determined by equipping them with a small GPS. Some location base protocols also have nodes working in sleep and active modes. GAF, GEAR are examples of location based routing.

2.9 Data Aggregation

Sensor nodes in a sensor networks periodically sense data, processes it and transmits it to the base station. How frequently a node sends data to the base station is application specific.

Data gathering is defined as collection of data in a systematic way from multiple sensor nodes to eventually transmit it to the base station for processing. Since the nodes in the sensor networks are driven by limited battery power and there is no scope of replenishment of battery power. It is inefficient to collect data from closely deployed nodes because data is highly correlated. Moreover in large sensor networks data generated is usually enormous for base station to process. Hence we need efficient approaches for combining data into high quality information at sensors or intermediate nodes which can reduce the amount of information sent to the base station and hence conserve energy and bandwidth. This goal can be achieved by data aggregation.

Data aggregation is defined as aggregating data from multiple sensors to convert it into small sets of quality information by eliminating redundant information and sending fused information to the base station (BS). There are various algorithms proposed for data aggregation.

In the case of WSN, a physical quantity is sensed. In real world, the environmental factors (e.g., temperature, humidity) change continuously instead of flipping over along the space field. According to this natural phenomenon, there exists kind of correlation in the data gathered from natural environment. Hence in WSN, data aggregation can be done by exploiting the correlation among the data. This would save time and energy. One way to exploit correlation is a linear transform in which the statistically dependent data will be mapped into a set of more independent coefficients and then compressed and transmitted.

2.10 Challenges In Wireless Sensor Networks

These days WSNs are finding their application in almost everywhere, but there are some issues related with these networks which worth attention whenever we work with them. These are as follows:

2.10.1 Energy

These networks are made up of very large number of nodes which sometimes approach order of 10^6 and are deployed inside the phenomenon or in close proximity. These tiny nodes have very little amount of energy with them. Due to the small size of these nodes which make these networks so special, these cannot carry heavy batteries with them. So in these networks energy usage should be optimum. This optimum usage poses a great challenge for researchers to develop some protocols so that fair use of energy can be there.

2.10.2 System Lifetime

As mentioned earlier these networks are limited battery driven networks which implies if battery goes off then network will die out and it will fail. So to increase the lifetime of the network various methodologies can be used which encourages scientists to go deeper into the field of WSN.

2.10.3 Production Cost

Earlier macro sensor networks had large sized nodes which were less in number in a particular network. But these days WSN have a large number of tiny sensor nodes. If production cost of each sensor node will be high then the whole network will not be economical to deploy for certain phenomenon. So the sensors cost should be as low as possible so that a network in a whole should not be much expensive.

2.10.4 Power Consumption

In WSNs there are three processes in which energy is consumed which are explained as follows:

2.10.4.1 Data Sensing

In this mode the deployed sensor nodes sense the phenomenon and acquire data. Sensor can be a temperature sensor, pressure sensor or whatever is suitable as per application. This is also called as data acquisition as data is acquired. Some power is consumed in this process.

2.10.4.2 Data Processing

Whole data sensed by these sensors is processed and as the sensors are deployed close to each other so the highly correlated data is processed so that only relevant information is forwarded to next node and in the end to base station. Some of the power is expended here.

2.10.4.3 Data Communication

The processed data is forwarded to the next nodes hop by hop and all the nodes collect data using data aggregation algorithms and process it and then forward it to valid station. This is the most expensive phase as this provides whole connectivity in the network.

So in a WSN these are processes where major portion of energy is consumed. Power expense in these processes should be minimized to enhance the lifespan and hence the reliability of the system which is a great field of research these days.

2.11 Advantages of Wireless Sensor Networks

Today is the era of micro scale technologies and WSNs is such a technology which is getting implemented into every sphere .It has revolutionised the world around us and are becoming essential part of our lives because of the advantage mentioned below:

2.11.1 Fault Tolerance

In WSN many sensor nodes are close to each other and have highly correlated information with each other, and this highly correlated information make WSN more fault tolerant. In a micro sensor network if some number of the nodes fail then whole network does not go down and the system generates adequate qualitative information. Moreover, if some node falling in the routing path fails then it parent node takes alternate route to transmit the message.

2.11.2 Improved Accuracy

If nodes are deployed individually and far away from each other then data accuracy will not be there. As in WSN all the nodes are in close proximity of each other and are sensing the same event, then their sensed data can be gathered. It will result in better accuracy of sensed data and reduced uncorrelated noise.

2.11.3 Extended Range of Sensing

In WSN large number of small nodes are deployed which overlap each other and they cover extensive ranges.

2.11.4 Ease of Deployment

In WSN there are a large number of nodes and these nodes can be deployed in remote areas which are not accessible by humans directly. These nodes can be deployed via throwing from aircrafts, or can be thrown using catapults etc.

2.12 Generations of Sensor Networks

Same as evolution of other technologies, evolution of Wireless Sensor Networks can be shown in terms of generations:

2.12.1 First generation Sensor Networks (1GSN)

A sensor network consisting of individual sensor devices. Sensor devices are deployed manually. Network is preconfigured entirely. Access to information is via manual recovery of the devices itself or long range point to point communication links.

2.12.2 Second Generation Sensor Networks (2GSN)

Sensor networks work in co-operation to cover up an area. The network on average consists of small amount of sensors communicating with a control node equipped with reach back link. They are naturally physically deployed, relying closely on pre configuration.

2.12.3 Third Generation Sensor Networks (3GSN)

The third generation of sensors encompasses self-organizing, scalable and flexible networks. Sensors communicate with one another for two purposes: Communication services (e.g. automatic relaying of message to a network gateway) and In-network processing (data aggregation and data fusion)

2.13 Wireless Sensor Network Application

These days wireless sensor networks are in every sphere. All these applications of Wireless Sensor Networks can be classified into three categories:

- Monitoring Space
- Monitoring Things
- Monitoring the connections of things with each other and the surrounding space.

2.13.1 Military Applications

The autonomy, self-configuration, self-organization and portability characteristics of a WSN make them very suitable for military applications. Since sensor networks are based on the dense deploymentof disposable and low-cost sensor nodes, destruction of some nodes by hostile actions does not affect a military operation as much as the destruction of a traditional sensor, which makes sensor networks concept a better approach for battlefields. The precise and well-timed gathering of visual observation and intellect data can play a role in attaining objectives as well as minimizing loss of human lives.

Table 2.2 Application of Wireless Sensor Networks

Military	Environmental	Health	Home	Industrial
Smart Dust	Flood Detection	Artificial Retina	Water Monitoring	Preventive Maintenance
Sniper Detection	Volcano Monitoring	Patient Monitoring		Structural Health Monitoring
Vigil Net	Zebra Net	Emergency Response		Vigil Net

It can be used:

- For commanders to monitor the status (position, quantity, availability) of their troops equipment and ammunitions.
- For battlefield surveillance or reconnaissance of opposing forces and terrain.
- For Flight spoil appraisal.
- To target the opponent, to notice biological and chemical (NBC) harass.

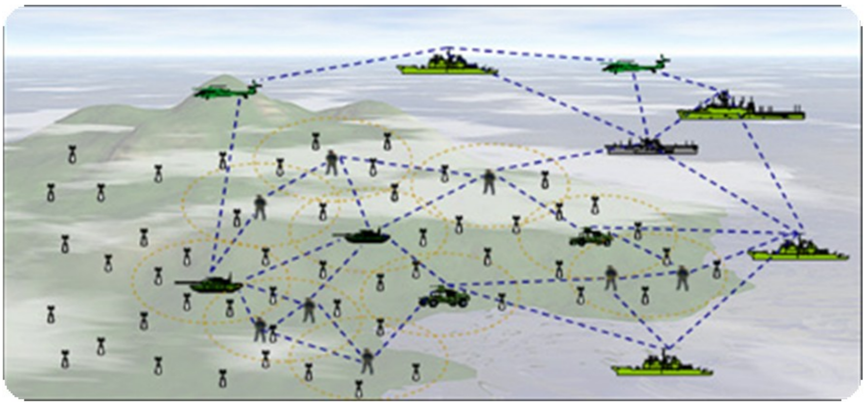


Fig.2.4 Military Monitoring

2.13.2 Environmental application

The autonomous coordination capabilities of WSNs are utilized in the realization of a wide variety of environmental applications. Some environmental applications of WSNs include tracking the movements of birds, small animals, and insects; monitoring environmental conditions that affect crops and livestock; irrigation; macro instruments for large-scale Earth monitoring and planetary exploration;

Chemical/biological detection; precision agriculture; biological, Earth, and environmental monitoring in marine, soil, and atmospheric contexts; forest fire detection; meteorological or geophysical research;

Flood detection; bio complexity mapping of the environment; and pollution studies.

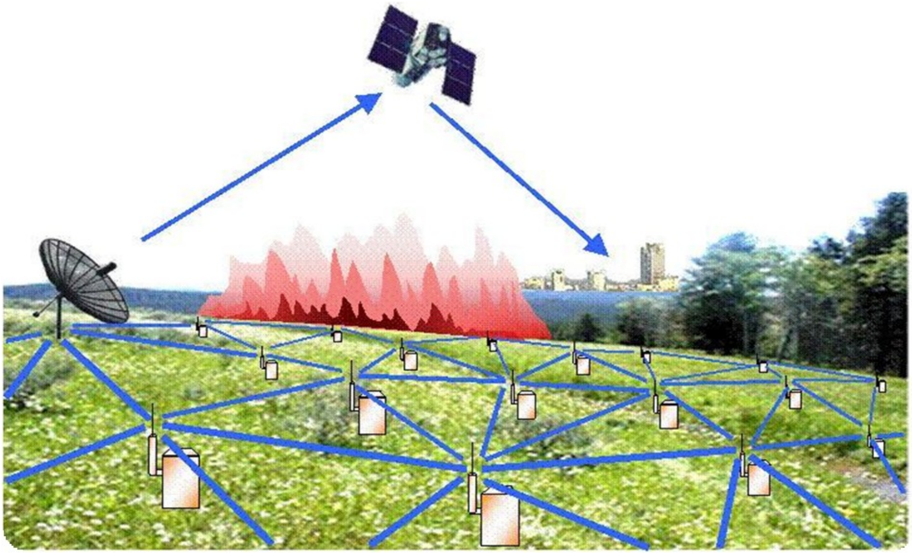


Fig.2.5 Forest Fire Detection

2.13.3 Health Applications

The developments in implanted biomedical devices and smart integrated sensors make the usage of sensor networks for biomedical applications possible. Some of the health applications for sensor networks are the provision of interfaces for the disabled; integrated patient monitoring; diagnostics; drug administration in hospitals; monitoring the movements and internal processes of insects or other small animals; telemonitoring of human physiological data; and tracking and monitoring doctors and patients inside a hospital

2.13.4 Home Applications

As technology advances, smart sensor nodes and actuators can be buried in appliances such as vacuum cleaners, microwave ovens, refrigerators, and DVD players as well as water monitoring systems. These sensor nodes inside domestic devices can interact with each other and with the external network via the Internet or satellite. They allow end-users to more easily manage home devices both locally and remotely. Accordingly, WSNs enable the interconnection of various devices at residential places with convenient control of various applications at home.

2.13.5 Industrial Applications

Networks of wired sensors have long been used in industrial fields such as industrial sensing and control applications, building automation, and access control. However, the cost associated with the deployment of wired sensors limits the applicability of these systems. Moreover, even if a sensor system were deployed in an industrial plant, upgrading this system would cost almost as much as a new system. In addition to sensor-based monitoring systems, manual monitoring has also been used in industrial applications for preventive maintenance. Manual monitoring is generally performed by experienced personnel using handheld analyzers that are collected from a central location for analysis. While sensor-based systems incur high deployment costs, manual systems have limited accuracy and require personnel. Instead, WSNs are a promising alternative solution for these systems due to their ease of deployment, high granularity, and high accuracy provided through battery-powered wireless communication units. Some of the commercial applications are monitoring material fatigue; building virtual keyboards; managing inventory; monitoring product quality; constructing smart office spaces; environmental control of office buildings; robot control and guidance in automatic manufacturing environments; interactive toys; interactive museums; factory process control and automation; monitoring disaster areas; smart structures with embedded sensor nodes; machine diagnosis; transportation; factory instrumentation; local control of actuators; detecting and monitoring car theft; vehicle tracking and detection; instrumentation of semiconductor processing chambers, rotating machinery, wind tunnels, and anechoic chambers; and distributed spectrum sensing to help realize cognitive radio networks

CHAPTER 3

LITERATURE REVIEW

3.1 Wireless Propagation Models

In wireless communications, signals travel from sender to receiver through the radio channel. These signals, which are sent at a particular power by the transmitter, suffer attenuation in the radio channel. The receiver, at the other end, is only able to receive the sender's transmission if the signal is received with a power level greater than the sensitivity of its transceiver. The attenuation, commonly known as the path loss of the channel, directly depends on the distance between sender and receiver, the frequency of operation and other factors. Path loss models exist to predict if there is a radio channel between two nodes. There are the two most commonly known path loss models explained in the next section: the free space model and the two ray ground model.

3.1.1 The Free Space Propagation Model

The Friis' free-space propagation model applies when there is a direct and unobstructed path between sender and receiver, that is, there is a line of sight. The received power at a distance d $\geq d_0$ meters between sender and receiver is given by Friis' path loss equation.

$$Prx(d) = \frac{Ptx \times Gtx \times Grx \times \lambda^2}{(4\pi)^2 \times d^2 \times L} = Cf \times \frac{Ptx}{d^2}$$

Where P*rx*(d) is the power received at the receiver over distance d, P*tx* is the power at which the signal was transmitted, G*tx* and G*rx* are the gains of the antennae of the transmitter and receiver, respectively, $L \geq 1$ includes the losses in the transmitter and receiver circuits, λ is the wavelength in meters, and Cf is a constant that depends on the transceivers.

As it can be seen from the equation, the signal attenuates proportional to the square of the distance d that it has to travel. From the transmitter's point of view, the above equation says that a disk of radius $r = \sqrt{Cf \times Ptx}$ is created and centered at the node equivalent to its area of coverage.

3.1.2 The Two – Ray Ground Model

The two - ray ground model assumes a more realistic scenario in which the receiver receives signals that travel directly from the sender to receiver and other signals that reach the receiver. This model is more accurate than the Friis' free space model. The power received at the receiver over distance d is given by the following equation.

$$Prx(d) = \frac{Ptx \times Gtx \times Grx \times htx^2 \times hrx^2}{d^4} = Ct \times \frac{Ptx}{d^4}$$

Where h*tx* is the height of the antenna of the transmitter, h*rx* is the height of the antenna of the receiver, G*tx* and G*rx* are the gains of the antennae of the transmitter and the receiver, respectively, P*tx* is the power at which the signal is transmitted, and C*t* is a constant that depends on the transceivers. As it can be seen from the equation with the two – ray ground model, the signal now attenuates proportional to the fourth power of the distance d. Therefore, the transmitter has now a disk of radius $r = \sqrt[4]{Ct \times Ptx}$ equivalent to its area of coverage.

3.2 Existing Wireless Sensor Networks Models

A great deal of research is going on to make algorithms and there resultant models to make optimum usage of battery power. There are various models given by various researchers and every model focuses on optimum usage of battery power by one or another means. These models expend different energies in different processes and some of them are as follows:

- Direct Transmission Model
- LEACH (Low Energy Adaptive Clustering Hierarchy)
- Minimum Transmission Energy Model

3.2.1 Direct Transmission Model

In this energy model all the sensor nodes are directly connected to the base station and directly send sensed data to the base station. Whole network architecture is flat architecture. There is no hierarchy of nodes. Whenever information is transmitted form a node to another node wirelessly energy is dissipated in accordance to distance between the nodes i.e. energy dissipation follows order of (distance between nodes) ^{n}. Value of n depends upon the channel characteristics. Say we have two nodes A and B 2m apart with initial energy of 1 J and transmission requires transmission energy(E_T) = 2nJ and receiving requires receiving energy(E_r) = 1nJ . If n=2 and A is transmitting to B then if B is lying in the transmission range of AA will expend $(2*10^{-9})$ k + c $(2)^2$ where c and k are some constants. But, if B is not in transmission range of A it will expend $(2*10^{-9})$ k + c $(2)^4$energy. If nodes are directly connected to base station then some will follow d^2 dissipation and some will follow d^4 model. For distances greater than transmission range of sensor nodes this model will expend a huge amount of energy but for distances less than the transmission range of the sensor nodes this will expend less amount of energy. So depending upon the requirements hierarchy of nodes can be introduced in the network. Hierarchy of sensor nodes will decrease the energy usage of the network. We simulated a network of 10 nodes and following figure shows the direct transmission model.

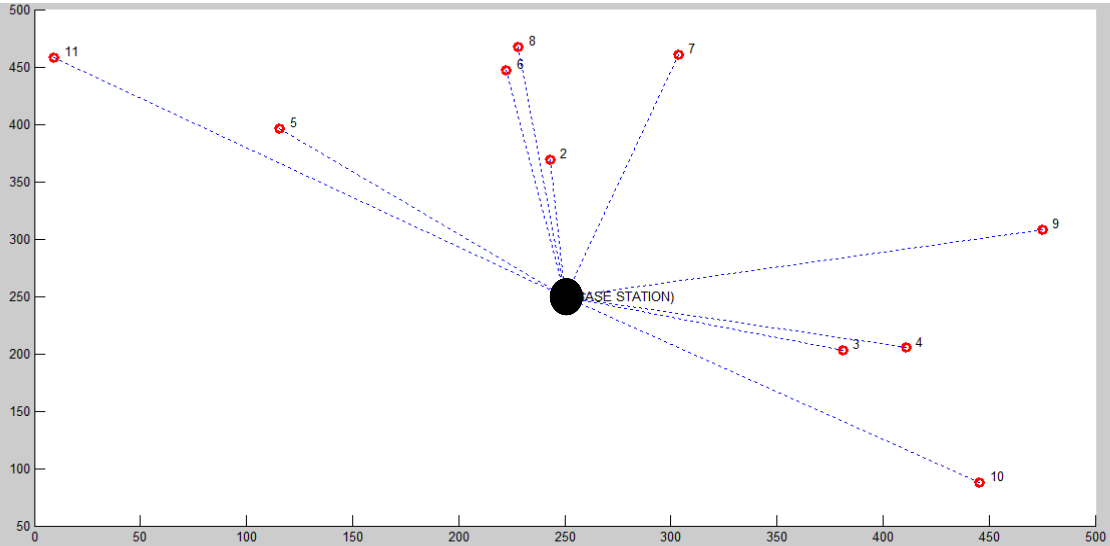


Fig. 3.1 Direct Transmission Model

3.2.2 LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the local base station or *cluster-head*. If the cluster heads were chosen a priori and fixed throughout the system lifetime, as in conventional clustering algorithms, it is easy to see that the unlucky sensors chosen to be cluster-heads would die quickly, ending the useful lifetime of all nodes belonging to those clusters. Thus LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor. In addition, LEACH performs local data fusion to “compress” the amount of data being sent from the clusters to the base station, further reducing energy dissipation and enhancing system lifetime. Sensors elect themselves to be local cluster-heads at any given time with a certain probability. These cluster head nodes broadcast their status to the other sensors in the network. Each sensor node determines to which cluster it wants to belong by choosing the cluster-head that requires the minimum communication energy.

Once all the nodes are organized into clusters, each cluster-head creates schedule for the nodes in its cluster. This allows the radio components of each non-cluster-head node to be turned off at all times except during it's transmit time, thus minimizing the energy dissipated in the individual sensors. Once the cluster-head has all the data from the nodes in its cluster, the cluster-head node aggregates the data and then transmits the compressed data to the base station. Since the base station is far away in the scenario we are examining, this is a high energy transmission. However, since there are only a few cluster-heads, this only affects a small number of nodes.

The system can determine, a priori, the optimal number of clusters to have in the system. This will depend on several parameters, such as the network topology and the relative costs of computation versus communication. We simulated a 10 node LEACH network .Fig 3.2 shows the simulated LEACH network.

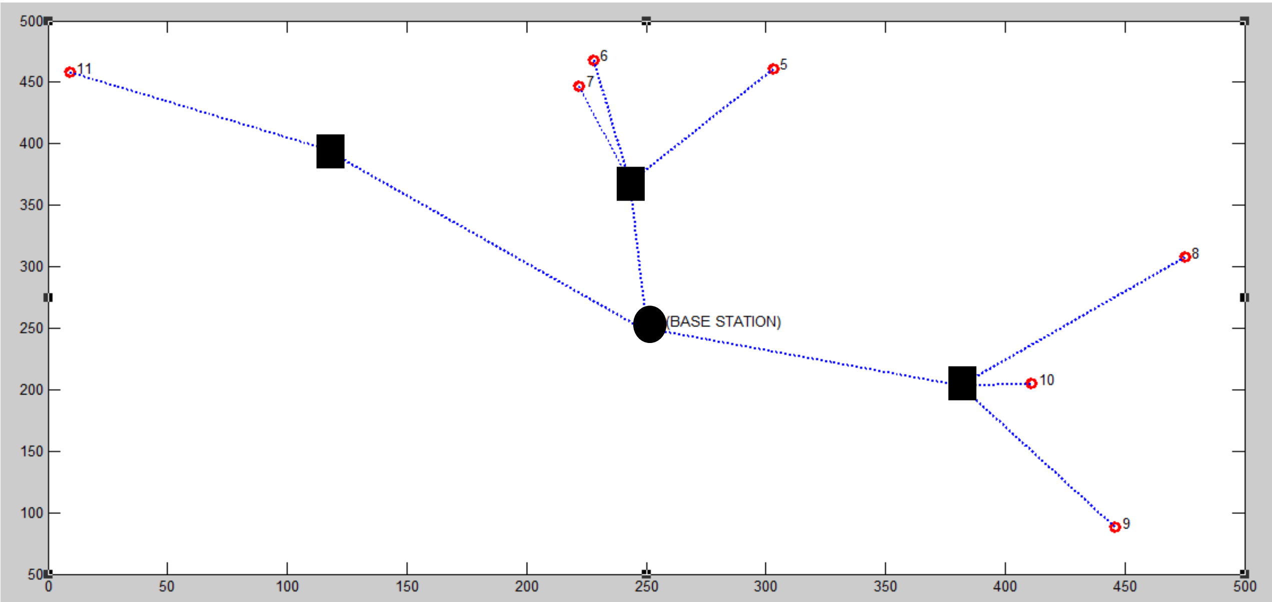


Fig. 3.2 10 Nodes of Leach Network

3.2.3 Minimum Transmission Energy Model (MTE)

Minimum Energy transmission model as the name signifies is a model in which considerably lesser amount of energy is used. This is quite similar to LEACH with some differences. Some of these are, in LEACH all the cluster heads are directly connected to the base station, but in this model a cluster head need not to directly connect to the base station. It depends upon the distance of cluster head from base station. If the base station is in the transmission range of the cluster head then it will directly connect to the BS, otherwise it will connect to base station via another cluster head. This point is explained in Fig 3.3.

Another difference between minimum energy transmission and LEACH is that there is static clustering in MTE i.e. once clusters are decided they will not change in their lifetime. In contrast to this clustering in LEACH is dynamic. After certain number of rounds process of selection of cluster heads and hence clusters repeat. This facilitates the optimized energy usage as functionalities are distributed on all the nodes.

All these models explained above have their own advantages and disadvantages. After studying and considering all the factors involved in the design of network architecture and keeping in mind the limitations we propose a model which is advanced version of minimum energy model and includes merging along with some new features viz. data aggregation ,fusion etc.

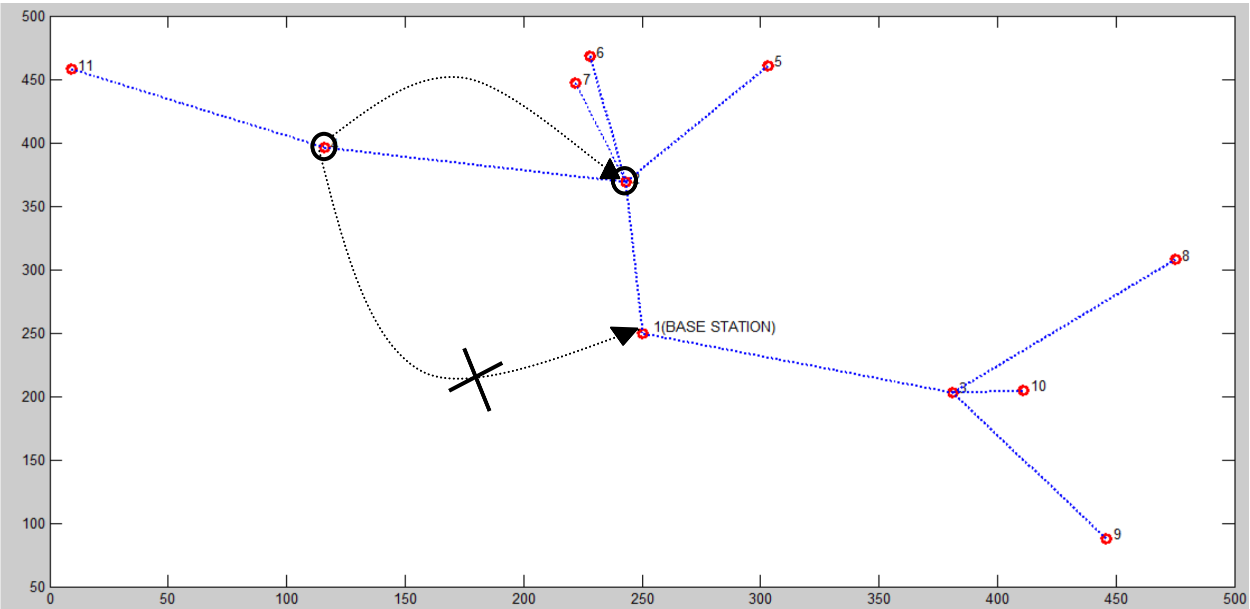


Fig. 3.3 Minimum Energy Transmission Model

3.3 LEACH Algorithm Details

The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

3.3.1 Advertisement Phase

Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing 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. The Threshold is set as:

$$\mathrm{T(n)} = \frac{\mathrm{P}}{(1 - \mathrm{P} * (\mathrm{rmod}\frac{1}{\mathrm{P}}))}$$

Where P = the desired percentage of cluster heads, r= current round, and g is set of nodes that have not been cluster heads in last $\frac{1}{\mathrm{P}}$ rounds.Using this threshold, each node will be a cluster-head at some point within $\frac{1}{P}$rounds. During round 0 (r=0), each node has a probability P of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next $\frac{1}{P}$ rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodes that are eligible to become cluster-heads. After $\frac{1}{P} - 1$ rounds, T=1 for any nodes that have not yet been cluster-heads, and after $\frac{1}{P}$rounds, all nodes are once again eligible to become cluster-heads.

Each node that has elected itself a cluster-head for the current round broadcasts an advertisement message to the rest of the nodes. For this "cluster-head-advertisement" phase, the cluster-heads use a CSMAMAC protocol, and all cluster-heads transmit their advertisement using the same transmit energy. The non-cluster-head nodes must keep their receivers on during this phase of set-up to hear the advertisements of all the cluster-head nodes. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement. Assuming symmetric propagation channels, the cluster-head advertisement heard with the largest signal strength is the cluster-head to whom the minimum amount of transmitted energy is needed for communication. In the case of ties, a random cluster-head is chosen.

3.3.2 Cluster Setup Phase

Once a node has decided to which cluster it belongs, it must inform cluster head about this. Each node transmit back this information to cluster heads using CSMA MAC protocol. To receive this information all the cluster heads must keep their receivers on.

3.3.3 Schedule Creation

Once it is decide to which cluster which node belongs depending upon the number of nodes in a cluster, cluster head creates a TDMA schedule specifying each node when it can transmit. This information is broadcasted back to the sensor nodes.

3.3.4 Data Transmission

Once the schedule is made nodes start sensing sensed data in their respective lots. Cluster heads receive information from the sensor nodes processes it, compresses it, convert it into single signal and forward it to the base station. Cluster heads have to keep their receiver on for all the time to receive information from various nodes.

This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins with each node determining if it should be a cluster-head for this round and advertising this information.

CHAPTER 4

PROPOSED MODEL

4.1 Introduction

This project is a further extension of minimum transmission model and leach protocol. To optimize the energy of the network we have included a new model called merging. As we know the sensor network are randomly and densely deployed in the monitoring region there is a possibility that many sensor nodes are very close to each other and sensing region of many sensor overlap with each other. This increases the probability of sending the same data again. Therefore, if two nodes are sensing the same area or if a node is falling in the sensing range (R_s) of another node connected to the same cluster head then it is of no use to sense same data using multiple sensors. This reduces the energy efficiency of the network and as we have limited available operating power for wireless networks, this will be a major reason for shortening the lifetime of network. An improvement over this approach is proposed merging algorithm.

4.2 Background

In our proposed model there is hierarchy of nodes in which first tier is composed of cluster heads and second tier consists of sensor nodes. Base station is assumed to have large amount of energy. All the sensor nodes will sense data and send it to base station via cluster heads. If the base station is out of the transmission range of the cluster head then it will also send its data via another cluster head which is in its transmission range. Cluster head through which it sends its data will aggregate all data and will then send it to base station which is in contrast with MTE model in which no doubt data came via cluster heads, but data of one cluster head is not aggregated at another cluster head through which it is coming. This is shown in Fig 4.1 and 4.2

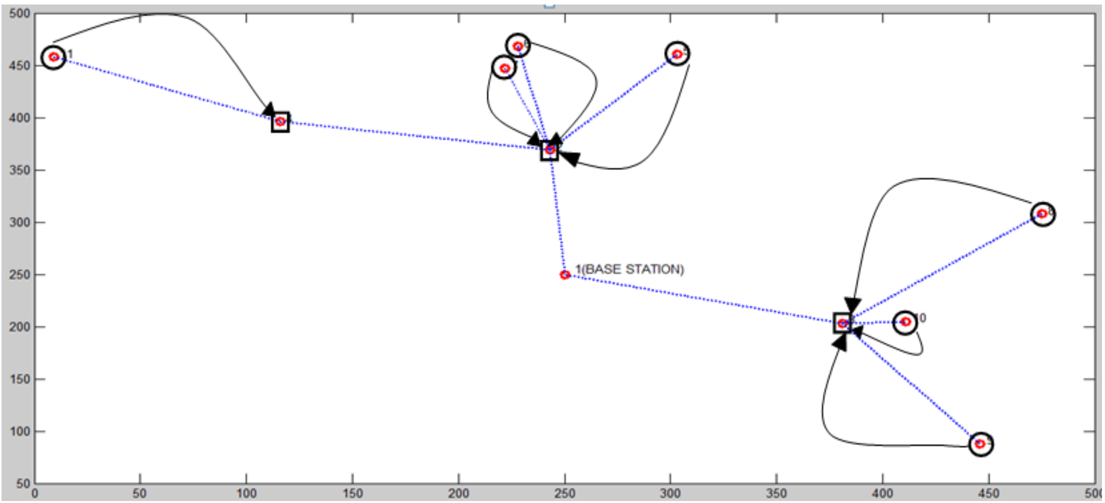


Fig 4.1 Proposed Model

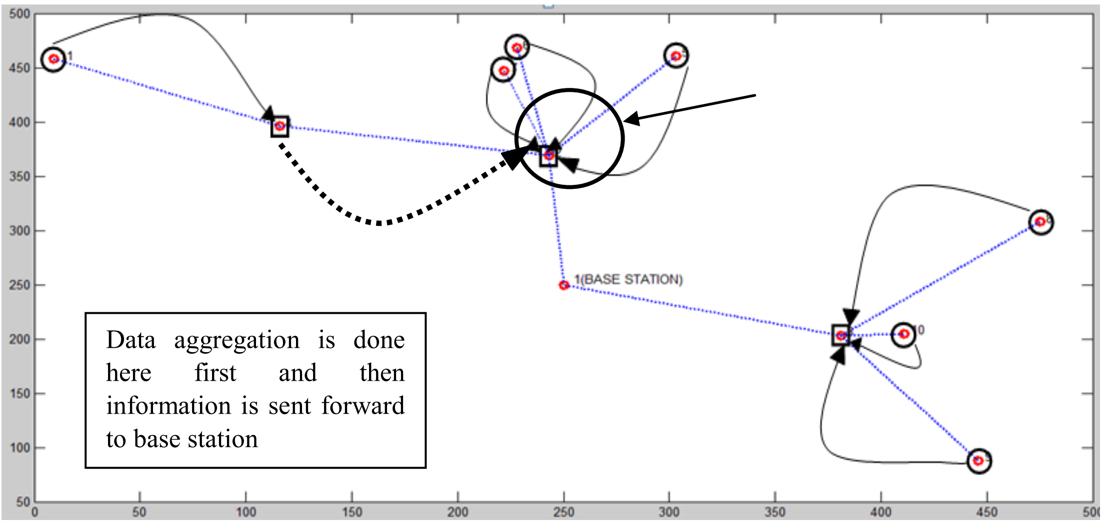


Fig 4.2 Data Aggregation in Proposed Model

4.3 Merging

Along with these minor improvements we introduced a new concept of merging. The idea behind merging is that if two nodes are sensing the same phenomenon and sensing it back to BS, then sensing the same phenomenon twice will be of no use. It is wastage of energy. So if this is happening then we can merge both the nodes and make them work as a single node. In other words we can say that if one is falling in the sensing range of another node or the footprint of two nodes is same then we can make them work in sleep and active mode with higher initial energy. This is shown in Fig. 4.3 .Node 6 and 7 are falling in sensing range of each other .So it's better to merge them and make them work in sleep and active mode.

As numbers of nodes are densely deployed in sensor networks, many nodes will merge together and a considerable amount of energy will be saved which also result in increased lifetime of network .As result network reliability will also increase. After merging overheads and network failures will be reduced considerably.

If nodes falling in the same sensing range then these nodes should work like one node with higher initial energy. Physically by merging we mean that these nodes will work in sleep and active mode with initial energy (E_0) higher than other nodes (say 1.5 J). This will save considerable amount of energy and hence lifetime of network increases. After the merging the above steps are repeated again to set the network again.

If ($d_{ij} \leq 75m$) merge n_i and n_j to node n_m

where

$$x_m = (x_i + x_j)/2 \ ,$$

$$y_m = (y_i+y_j)/2$$

Initial energy of merged node is 1.5 J

Update N to N-1

This is shown in Fig. 5. N6 and N7are merged as they fall in sensing range of each other.

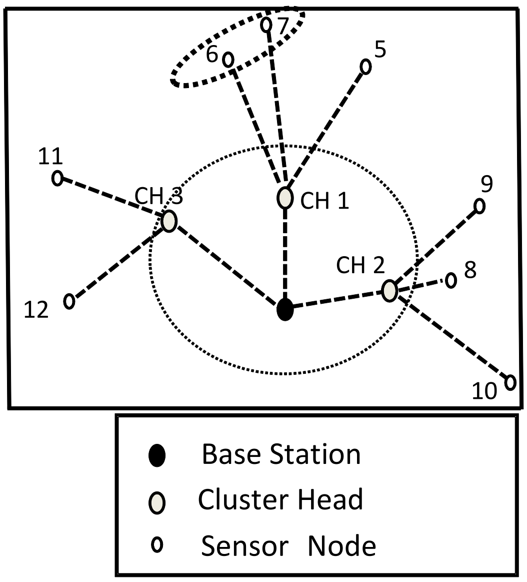


Fig 4.3 Merging of Nodes

Repeat the above steps and construct the new network having merged nodes and again calculate routing table and energy of nodes.For energy calculations we have used First Order Radio Model which is explained in the following section.

4.4 First Order Radio Model

Currently, 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 transmission and receiving modes, will change the advantages of different protocols. In our work, we assume a simple model where the radio dissipates E_{elec}= 50nJ/bit to run the transmitter or receiver circuitry and ε_{amp}=10pJ/bit/m^2 for the transmit amplifier to achieve an acceptable E_b/N_o (see Table 4.1). These parameters are slightly better than the current state-of-the-art in radio design. We also assume an r^2 energy loss due to channel transmission.

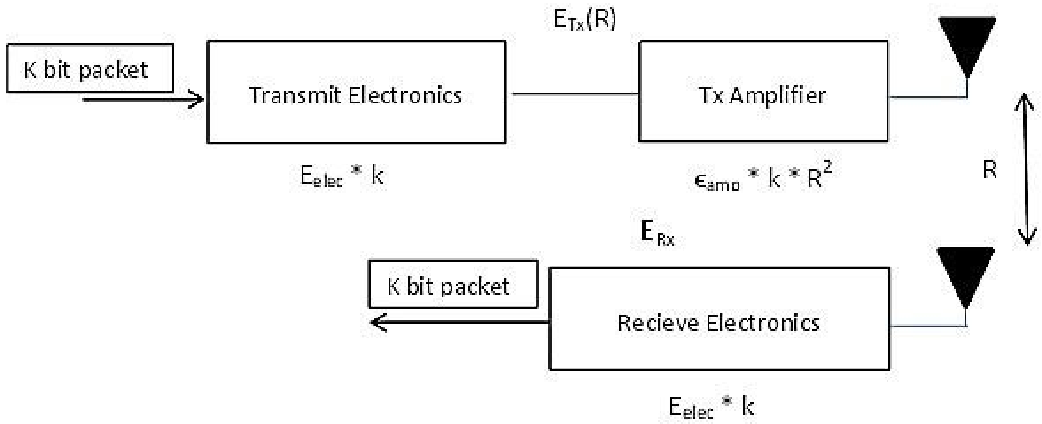


Fig 4.4 First Order Radio Model

Table 4.1 CONSTANTS IN FIRST ORDED RADIO MODEL

Operation	Energy Dissipated
Transmitter Electronics ($E_{Tx\text{-}elec}$) Receiver Electronics($E_{Rx\text{-}elec}$) ($E_{Tx-elec}$= $E_{Rx-elec}$ = E_{-elec})	50nJ/bit
Transmitter Amplifier(ε_{amp})	100pJ/bit/m^2

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

$$E_{Tx}(k, d_{ij}) = E_{Tx-elec}(k) + E_{Tx-fs}(k, d_{ij}) + E_{DA} \qquad (1)$$

$$E_{Tx}(k, d_{ij}) = E_{elec} * k + \varepsilon_{fs} * k * (d_{ij})^2 + E_{DA};\ d_{ij} < d_0 \qquad (2)$$

And receiver expends:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$

$$E_{Rx}(k) \quad = \quad E_{elec} * k \qquad (3)$$

ε_{fs}= 100 pJ/bit/m^2

E_{elec}= 50 nJ /bit

E_{DA} = 5 nJ/bit

For these parameter values, 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. We make the assumption that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. For our experiments, we also assume that all sensors are sensing the environment at a fixed rate and thus always have data to send to the end-user. For future versions of our protocol, we will implement an event-driven simulation, where sensors only transmit data if some event occurs in the environment.

4.5 Methodology

4.5.1 Assumptions

Notations used are described in Table 4.2

Table 4.2 NOTATION TABLE

Notation	Meaning
N	Total nodes in the network
E_0	Initial node energy (1J)
n_0	Node id of BS
n_i	Node id of ith node
K	Number of bits in one packet
E_{th}	Threshold energy value at which the CH die out.
E_{DA}	Data aggregation energy
R_s	Sensing Range
R_t	Transmitting Range
N_i	Set of neighbouring nodes of ith node

CH_{id}	Cluster head ID's for each nodes
E_r	Residual Energy < E_0
d_{ij}	Distance between i^{th} nodes to j^{th} node.
$Count_i$	The number of neighbouring nodes to the i^{th} node
$E_{sensing}$	Sensing energy
H_{id}	Number of hops to reach the BS
Nb_i	i^{th} hop neighbour of BS or i^{th} hop neighbor of nodes in $(i-1)^{th}$ hop

The network used for the current research work has the following properties:-

1. The nodes are homogenous having equal energy of 1 Joule.
2. The nodes transmit the data to the BS in multiple hops.
3. The hops are determined based on the distance of the node from the BS.
4. The sensors used have transmitting range of 100-150 m (Outdoor) and 50-75m (Indoor). Considering R_t (150 m) as the transmission range and R_s (75 m) as the sensing range, we have considered $R_t \geq 2R_s$ to be a valid assumption. According to [5], when the transmission range is at least twice the sensing range, this is because when two sensors have a common covered sensing area, there result are almost same as shown in Fig 4.5
5. Total N numbers of nodes are randomly deployed.
6. After random deployment sensor nodes are stationary.
7. BS (n_0) is fixed and deployed somewhere in the middle of the network (250,250).
8. All the nodes are proactive.

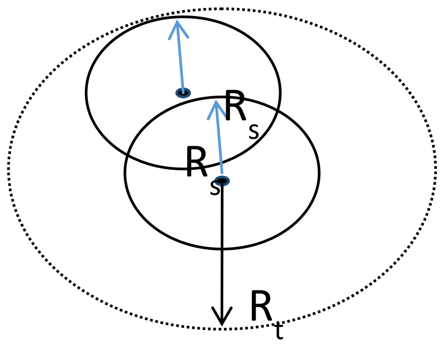


Fig 4.5 Transmission and Sensing Range

4.6 Algorithm

Step1: Firstly on considering 500*500 area, the nodes are deployed randomly. Here 10 nodes are being considered with base station at 250*250. Each sensor has a transmitting range (R_T) of 150m.

Step2: We then find out the distance matrix of all the nodes with each other.

0	232	198	218	119	254	139	219	318	167	199
232	0	370	230	240	222	141	294	490	121	289
198	370	0	198	130	451	328	133	124	351	118
218	230	198	0	110	399	270	75	294	278	82
119	240	130	110	0	347	216	100	250	235	81
254	222	451	399	347	0	132	438	573	122	423
139	141	328	270	216	132	0	306	451	30	291
219	294	133	75	100	438	306	0	219	320	22
318	490	124	294	250	573	451	219	0	475	213
167	121	351	278	235	122	30	320	475	0	307
199	289	118	82	81	423	291	22	213	307	0

Step3: The nodes in the range of the base station are connected to the base station.

Step4: The sensors deployed within the transmitting range are connected to the already connected node. Any node connected to more than one node is called a cluster head

Step5: This process goes on till all the required nodes are connected as shown in Fig 4.6.

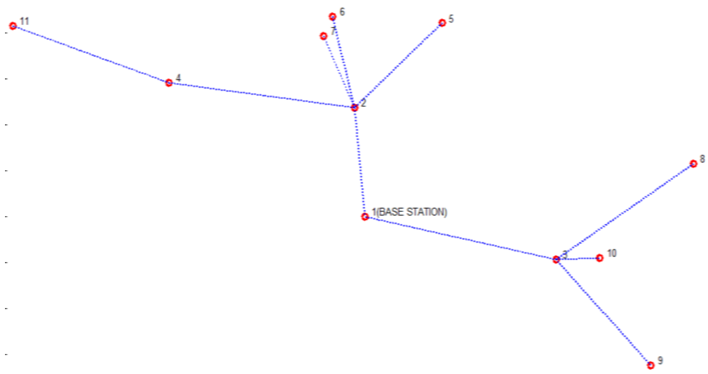


Fig 4.6 All the nodes connected to BS

Step6: During this process we also take out the loopID and the hopID

nodeID: [1 8 4 5 2 9 3 6 11 10 7]

loopID: [1 3 2 2 1 3 1 2 4 3 2]

hopID: [0 1 1 2 2 2 2 2 2 2 3]

- node Id is the numbering of the nodes which were randomly generated
- loopID tell us about the nodes after the first hop
- hopID tells about the no. of hops each node has to encounter

Step7: The next step was to calculate the routing table of the network. Using the above ID we find out the routing table of nodes in the network. Routing table gives us the routing path of every node.

Routing table:

1	0	0	0
2	1	0	0
3	1	0	0
4	2	1	0
5	2	1	0
6	2	1	0
7	2	1	0
8	3	1	0
9	3	1	0
10	3	1	0
11	4	2	1

Step8: We calculated the energy used in the transmission and receiving of nodes. We assume the initial energy of each node is 1J.

Energy =0.9970 0.9981 0.9990 0.9995 0.9995 0.9995 0.9995 0.9996 0.9995 0.9996

Step9: Once the energy of the node required in transmitting and receiving is determined the number of round the node will last can be predicted

Step10: For a more efficient performance of the network we merge the nodes who sense the same data or nodes at a distance less the 25m from each other. The merged coordinates are assumed to be:

$$X_m = (x_i + x_j)/2$$

$$Y_m = (y_i + y_j)/2$$

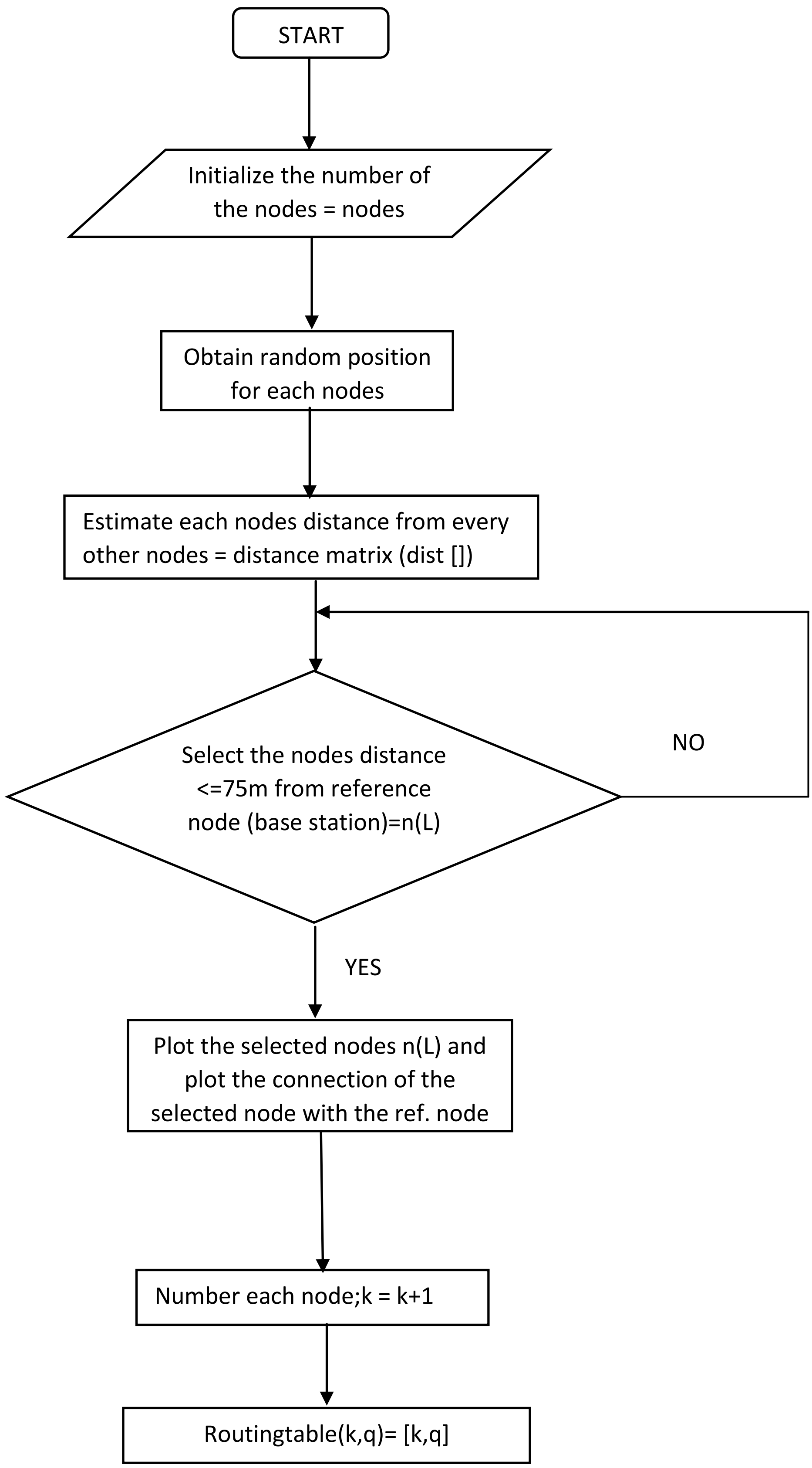
N_i and N_j are the nodes to me merged and n_m in the node the merged nodes with coordinated x_n and y_m

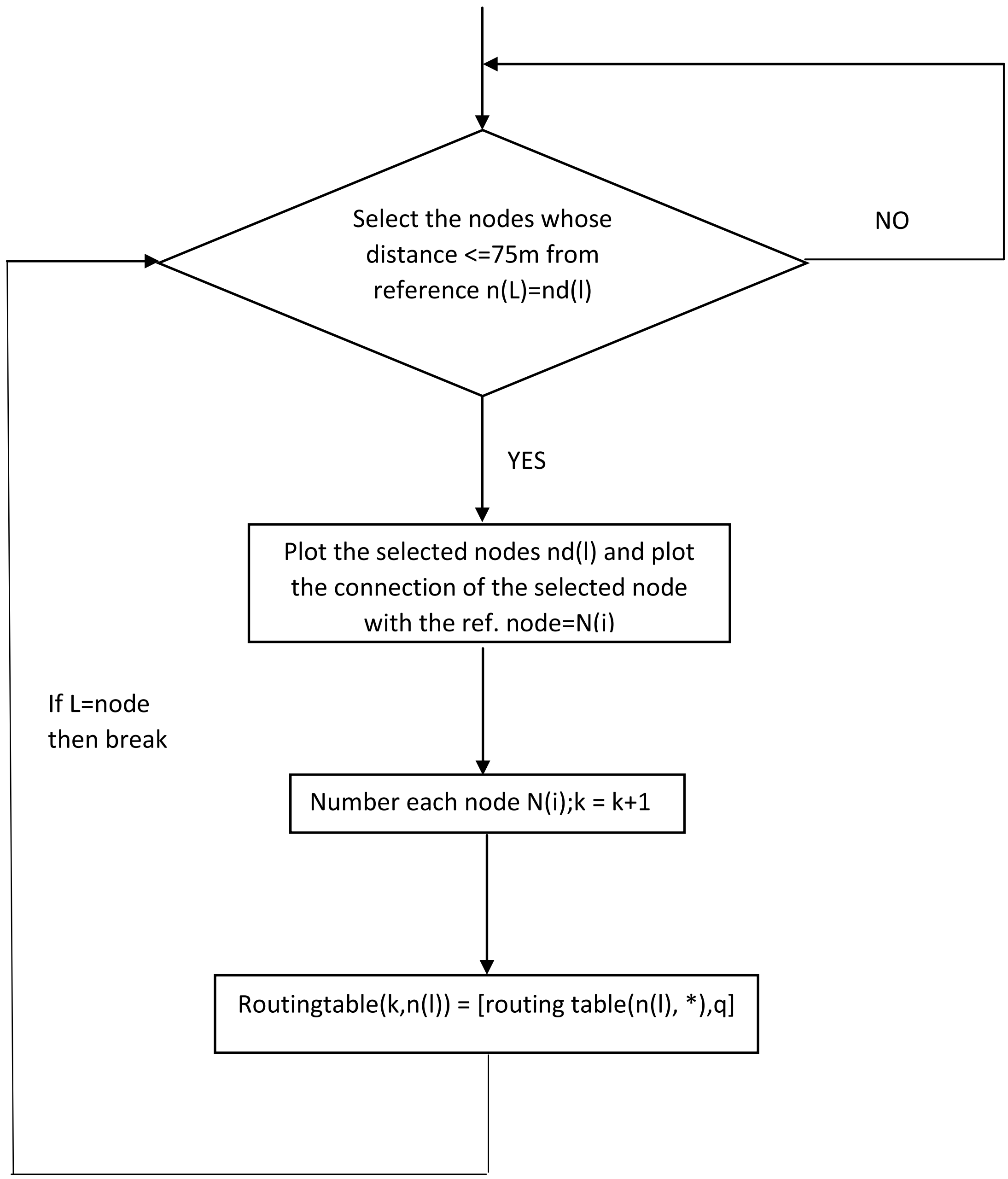
The merged nodes will have the initial energy of 1.5J

Step11: Repeat the above 8 steps for the new network and life time of the network increases as shown in the table.

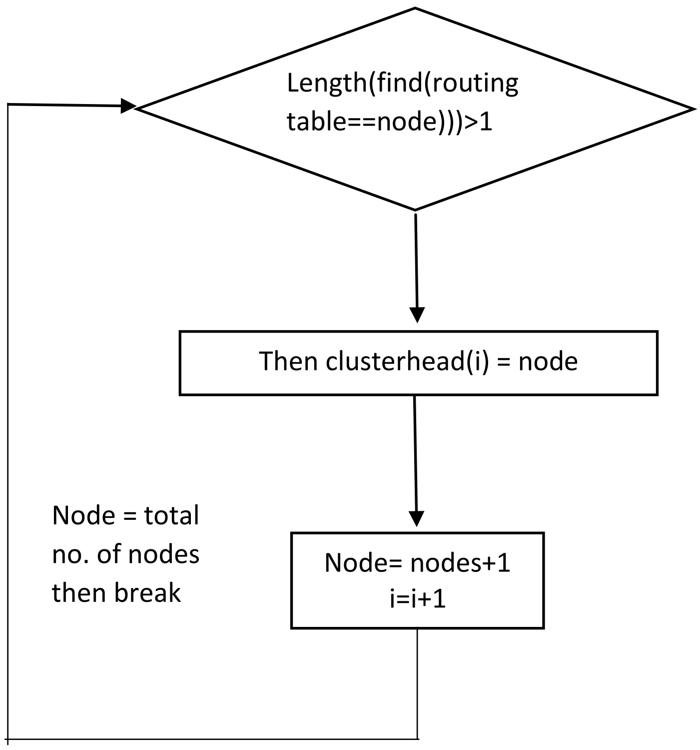
4.7 Flow Chart

Allocation and setup:

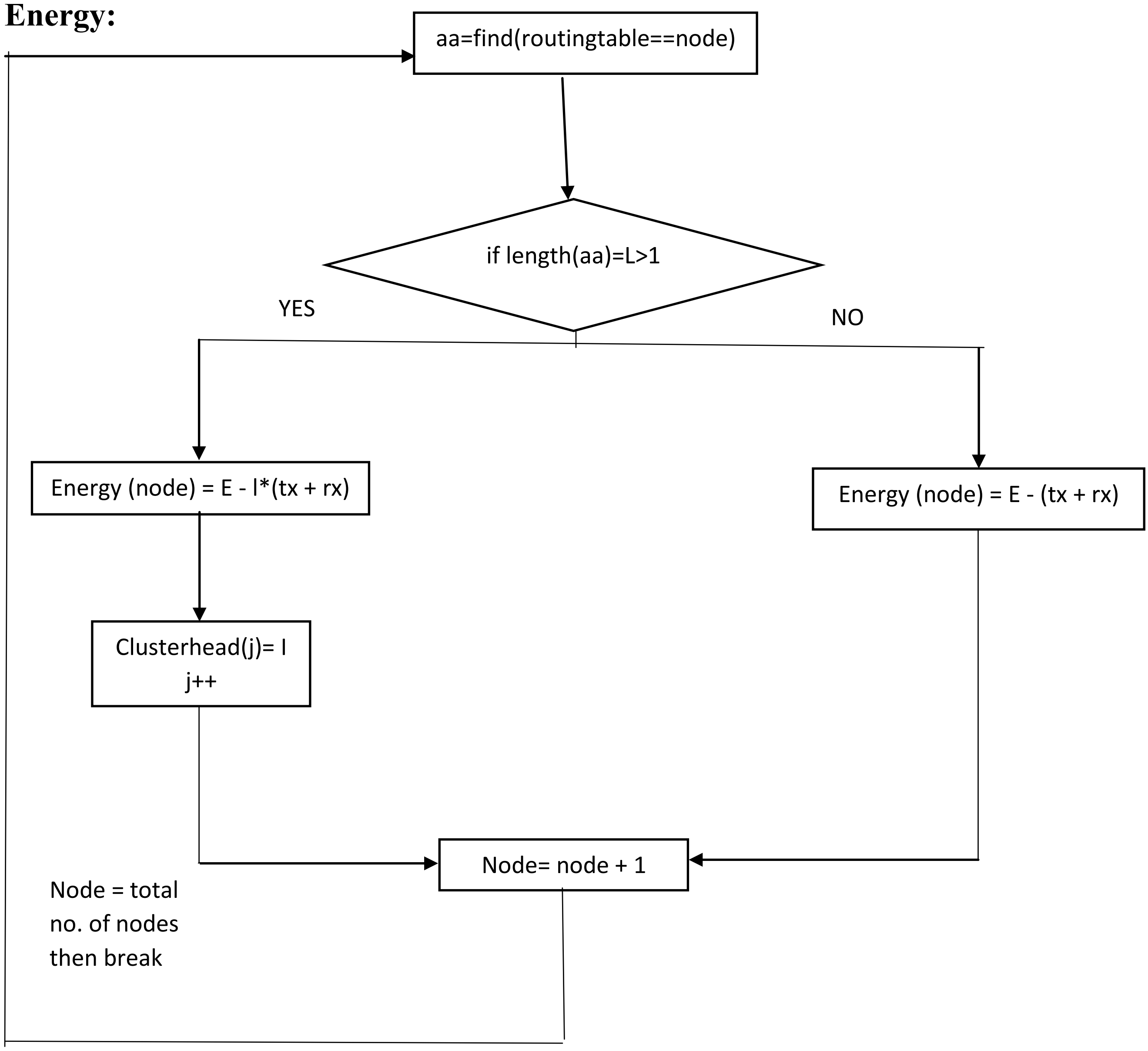



Select the nodes whose distance <=75m from reference n(L)=nd(l)
NO
YES
Plot the selected nodes nd(l) and plot the connection of the selected node with the ref. node=N(i)
If L=node then break
Number each node N(i);k = k+1
Routingtable(k,n(l)) = [routing table(n(l), *),q]

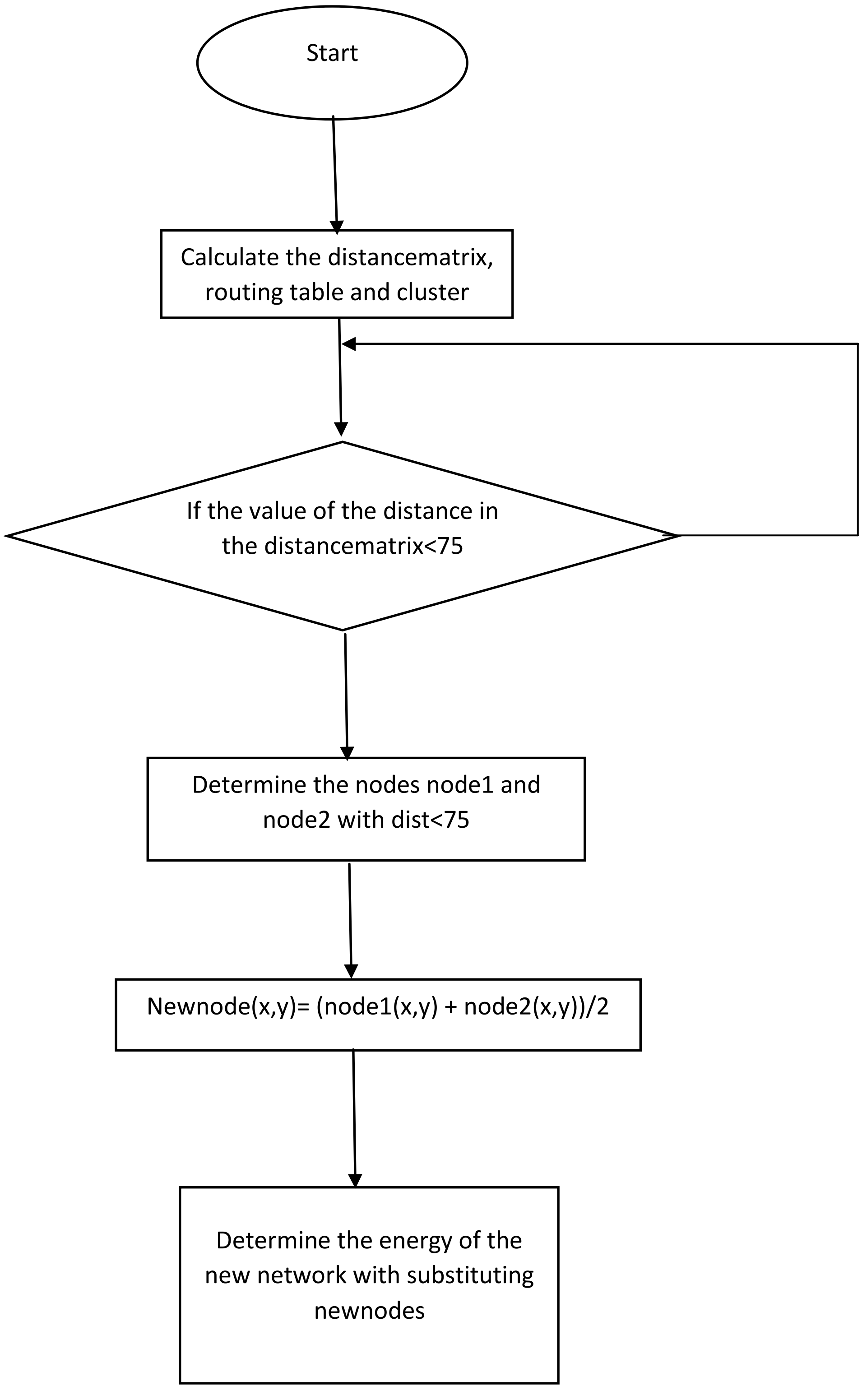
Clusterhead:



Energy:


aa=find(routingtable==node)
if length(aa)=L>1
YES
NO
Energy (node) = E - l*(tx + rx)
Energy (node) = E - (tx + rx)
Clusterhead(j)= l
j++
Node= node + 1
Node = total
no. of nodes
then break

Merging:


Start
Calculate the distancematrix, routing table and cluster
If the value of the distance in the distancematrix<75
Determine the nodes node1 and node2 with dist<75
Newnode(x,y)= (node1(x,y) + node2(x,y))/2
Determine the energy of the new network with substituting newnodes

CHAPTER 5

SIMULATIONS AND RESULTS

5.1 Simulation results computed using first order radio model

Based on the first order radio model the following Table 5.1 has been computed before merging. The Table shows the number of rounds required for the respective percentage of nodes to be alive for 50, 100, 200 and 300 taken as total number of nodes.

Table.5.1 Before Merging

%age nodes alive	***Total Number of Nodes***			
	50	***100***	***200***	***300***
100	**0**	**0**	**0**	**0**
75	**1963**	**1848**	**1752**	**1609**
50	**2143**	**1987**	**1843**	**1704**
25	**2304**	**2117**	**1923**	**1816**
10	**2577**	**2301**	**2027**	**1973**
9	**2598**	**2327**	**2093**	**1997**
5	**2657**	**2436**	**2186**	**2158**
3	**2699**	**2473**	**2317**	**2296**
1	**2705**	**2518**	**2391**	**2341**

The graph shows the tabulated results in Table 5.1 graphically.

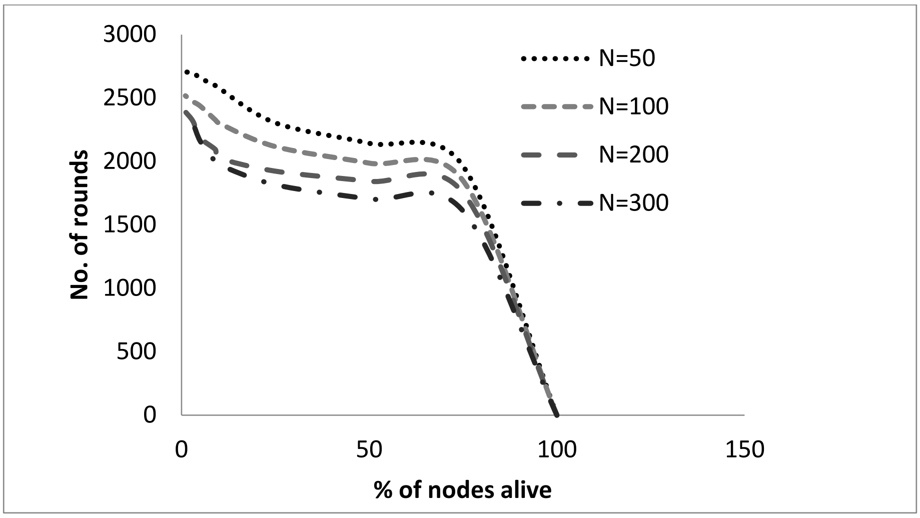


Fig. 5.1 Before Merging

The following Table has been computed after merging. The Table shows the number of rounds taken for 100, 75, 50, 25 and so on percentage of nodes to be alive when the total number of nodes taken was 50, 100, 200 and 300.

Table.5.2 After merging

%age nodes alive	***Total Number of Nodes***			
	50	***100***	***200***	***300***
100	**0**	**0**	**0**	**0**
75	**2763**	**2641**	**2503**	**2410**
50	**3149**	**3019**	**2917**	**2803**
25	**3517**	**3381**	**3209**	**3107**
10	**3819**	**3590**	**3401**	**3391**
9	**3903**	**3697**	**3519**	**3443**
5	**4185**	**3870**	**3697**	**3579**
3	**4353**	**4021**	**3821**	**3671**
1	**4591**	**4307**	**4152**	**3917**

The graph shows the above table graphically.

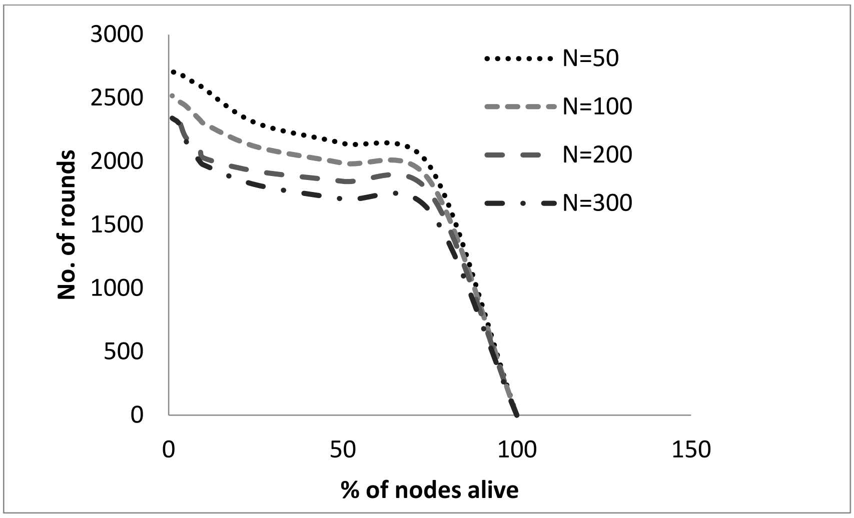


Fig. 5.2 After Merging

5.2 Comparison with other models

5.2.1 Proposed Model and Direct Transmission

The following Table compares the Proposed Model (PM) and Direct Transmission Model (DTM) for the total number of nodes 50.

Table.5.3 Comparison between Proposed Model and Direct Transmission Model

%age nodes alive	***Total number of nodes***	
	PM	***DTM***
	50	***50***
100	**0**	**0**
75	**2763**	**156**
50	**3149**	**224**
25	**3517**	**351**
10	**3819**	**440**
9	**3903**	**570**
5	**4185**	**620**
3	**4353**	**711**
1	**4591**	**790**

The comparison between the PM and DTM done graphically in the following Graph from the above Table5.3

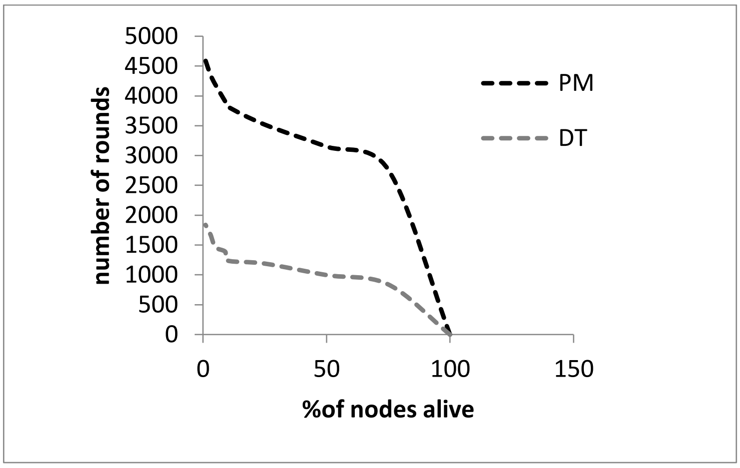


Fig. 5.3 Graphical Representation of Comparison between Proposed and Direct Transmission Model

5.2.2 Proposed Model and LEACH

The following Table compares the Proposed Model (PM) and LEACH for the total number of nodes 50.

Table.5.4 Comparison between Proposed Model and LEACH

%age nodes alive	***Total number of nodes***	
	PM	***LEACH***
	50	***50***
100	**0**	**0**
75	**2763**	**1848**
50	**3149**	**2014**
25	**3517**	**2156**
10	**3819**	**2210**
9	**3903**	**2287**
5	**4185**	**2356**
3	**4353**	**2401**
1	**4591**	**2490**

The comparison between the PM and LEACH is done graphically in the following Graph from the above Table 5.4

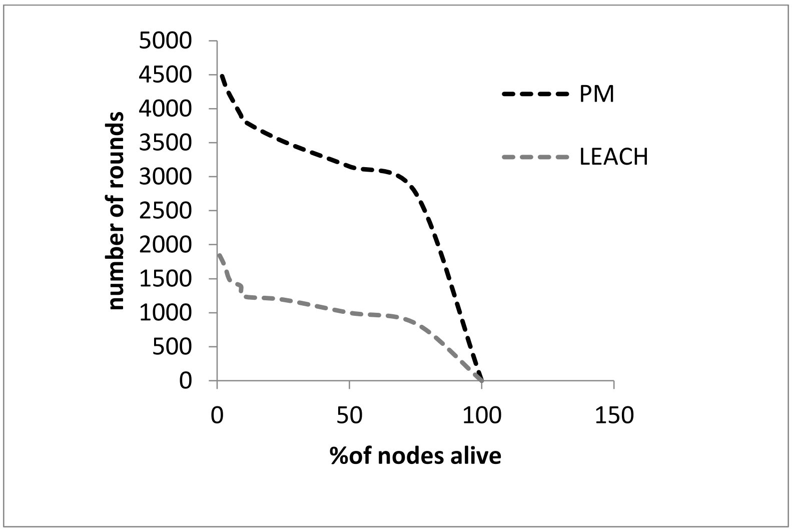


Fig. 5.4 Graphical Representation of Comparison between PM and LEACH

5.2.3 Proposed Model and Minimum Transmission Energy Model

The following Table compares the PM and Minimum Transmission Energy Model (MTE) for the total number of nodes 50.

Comparison between Proposed Model and Minimum Transmission Energy Model

%age nodes alive	***Total number of nodes***	
	PM	***MTE***
	50	***50***
100	**0**	**0**
75	**2763**	**841**
50	**3149**	**998**
25	**3517**	**1190**
10	**3819**	**1240**
9	**3903**	**1389**
5	**4185**	**1467**
3	**4353**	**1678**
1	**4591**	**1840**

The comparison between the PM and MTE is done graphically in the following Graph from the above Table 5.5

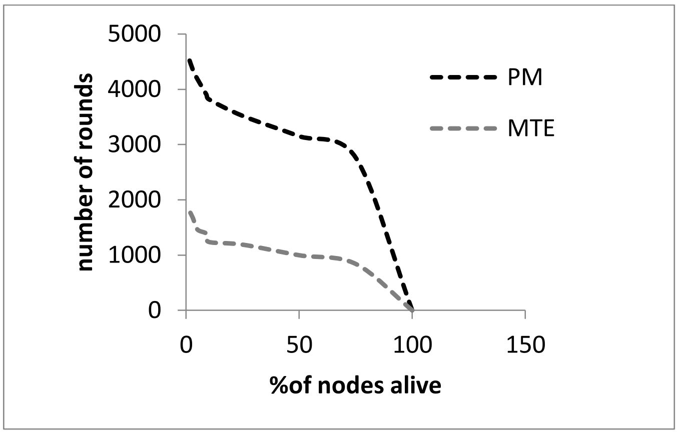


Fig. 5.5 Graphical Representation of Comparison between PM And MTE Model

CHAPTER 6

CONCLUSION AND FUTURE WORK

In this thesis we have mainly focused on energy optimization of a wireless sensor network using sensing range. Firstly we randomly deployed a number of nodes in a fixed region and on the basis of transmission distance clusters were formed. Then in the deployed network we computed the energy required for one round of transmission using the first order radio model. Later on the same network we applied the concept of merging. The concept of merging follows as, wherever the distance between two nodes in a cluster is less than or equal to half of the transmission distance then those two nodes are merged. Both these nodes now work in sleep and active modes. Merging also helps in removing redundant data which earlier before merging would have been sensed twice.

We simulated our model in the software MATLAB and compared the experimental results with other existing models such Direct Transmission Model, LEACH and Minimum Transmission Energy Model. After comparing our Proposed Model we can successfully conclude that the network lifetime is tremendously enhanced after applying merging in our deployed network.

Presently this Model was implemented using a homogeneous network and proactive nodes (nodes which always have data to transmit). In the future this Model can be extended to a heterogeneous network where nodes are differ from each other in terms of energy associated and functionality and also the nodes used could be reactive in nature.

This Model could be used in applications such as measuring the temperature or a pressure of a particular region.

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