CERTIFICATE

It is certified that the work contained in this thesis entitled **"An Advanced Approach For Reducing Energy Consumption In Wireless Sensor Network",** by **Abhishek Kumar** (Roll No. 1180454001), for the award of **Master of Technology** from Babu Banarasi Das University has been carried out under my supervision and that this work has not been submitted elsewhere for award of any degree.

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ABSTRACT

The popularity of Wireless Sensor Networks has increased tremendously due to the vast potential of the sensor networks to connect the physical world with the virtual world. Since these devices rely on battery power and they may deploy in hostile environments. Thus, improving the energy of these networks becomes important. Our thesis aims to optimize the energy consumption of wide scale wireless sensor networks by deploying a fraction of nodes with more energy & base station at the edge of the wireless sensor network field and randomize selection of cluster head which provide modification on the traditional clustering of the cells of the network. In our thesis we our load balancing of each cluster in the network by random selection of node as cluster head that may be either advance node (more energy) or normal node.

ACKNOWLEDGEMENT

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LIST OF SYMBOLS

$C_i(t)$	Cluster Head
DIS	Distance
$D^{2,}$ D^4	Power Loss
D_{TOCH}	Distance from the Node to the Cluster Head
D_{TOBS}	Distance from Cluster Head to the Base Station
$E_i(t)$	Current Energy
E_{TOTAL}	Total Energy
E_{ELEC}	Electronics Energy
$E_{CLUSTER}$	Energy dissipated in a cluster during the Frame
E_O	Initial Energy
E_{TX}	Transmission Energy
E_{RX}	Receive Energy
E_{FS}	Free Space Energy
E_{MP}	Multipath Energy
L	No. of Bits in Each Data Message
MOD	Modulation
MIN	Minimum
N	Node
Pi (t)	Probability
R_{MAX}	Maximum Round

RND	Random
Sqrt	Square Root
Temp	Temporarily

LIST OF ABBREVIATION

ADV	Advertisement Message
BS	Base Station
CH	Cluster Head
CSMA	Carrier Sense Multiple Access
DSSS	Direct Sequence Spread Spectrum
FDMA	Frequency Division Multiple Access
GPS	Global Positioning System
ID	Identity
JOIN-REQ	Join Request Message
LEACH	Low Energy Adaptive Clustering Hierarchy
MTE	Minimum Transmission Energy
MAC	Medium Access Control
PSTN	Public Switched Telephone Network
RF	Radio Frequency
TDMA	Time Division Multiple Access
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

Due to its extensive potential to connect the physical world with the virtual world, wireless based network of sensor nodes has been an attractive area for the researchers. There are potential applications in a range of fields for these large wireless networks, including medical monitoring, monitoring of the environment, home safety and machinery monitoring, military operations. It is expected in the coming decades, there is going to be an increased usage of sensor-based networks, around us. These sensor nodes would be used to monitor and provide effective environment data to the end user round the clock. As progress on micro-fabrication technology allows the cost of manufacturing sensor nodes to decrease continuously, the Wireless Sensor Networks would be both cost effective and extensively prevalent.

1.1 Wireless Sensor Network:

Wireless networks are considered as one of the futures newly developed computer technologies, moving closer to the widespread feasibility with the recent developments in Micro electro-mechanical systems technology, low-power digital circuitry and RF architecture. Different useful and varied WSN application usually involve information collection in rough and uninhibited settings, such as weather and climate tracking, the detachment of chemical or biological hazards to agents and safety tracking. Cheap and intelligent sensors linked through wireless Internet communication have remarkable aims for environmental control and tracking, houses, health care, the military, etc. This includes the use of different equipment including cameras, acoustics, infrareds and seismic instruments and sensors that calculate various physical parameters. In a variety of different situations, for example in military environments, a network of smart sensors can be deployed to detect various threats. These networks are therefore able to collect intelligence in combat areas, track enemy lines, monitor dangerous chemical and nuclear materials.

through neutrancy-based detectors and detect viruses, toxins using antiko-coated bio-Sensor chips to attract biological agents.

The standard cluster-based WSN architecture is shown in Figure 1.1. They detect the information by means of a node named cluster head node and transmit it to the base station. The cluster head adds the files, compresses them to the base station, then transmits them. The base station serves as an entrance to the other network to transfer the info. The base station data base provides the means for updating and retrieving the information on request.

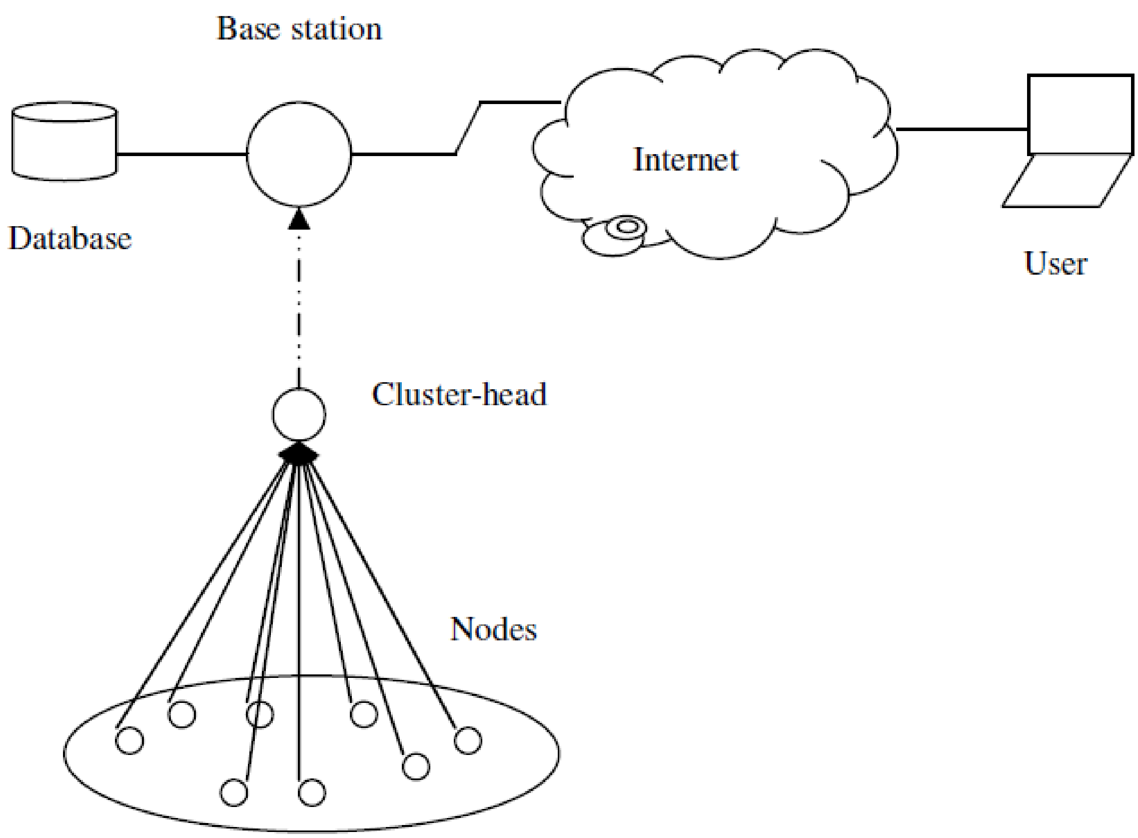

Figure 1.1: WSN architecture

1.2 Design Considerations:

The designing of Wireless Sensor Network protocols is a tedious task. There are a number of factors which must be taken into account.

- Network Lifetime is an important constraint due to limitation of power supplied to these nodes.
- There is high unreliability in the case of Wireless communication as compared to wired communication.
- WSN required to be self-configurable.
- The sensor nodes are fixed i.e. their location is not going to change in their entire working lifetime, so the existing protocols designed keeping in mind adhoc networks can not be used in case of Wireless sensor Networks.
- Another important consideration is the size of wireless Sensor Network. A wireless sensor network would typically consist of thousands of sensor nodes as compared to a few nodes in traditional networks.
- The environmental conditions can vary depending on the usage, sometimes extreme temperature and pressure considerations are required.
- The data packets sent over the network by wireless sensor nodes are very few thus the network layer overhead is essential.
- Wireless sensor nodes need to be co-operative in nature and should work in co-ordination to each other.
- In wireless sensor nodes the routing may follow a number of distinct patterns. These patterns can be classified as given below:

  (1) Many to one: Individual nodes may send their sensed data packets to one node which aggregates and sends it to base station.

(2) One to many: distinct control and association signals to sensor nodes from the base station or cluster head multicasts (or broadcasts).

(3) Local communication: in some topologies, nodes should be discovered and coordinated in the form of communication.

1.3 Hardware Architecture of Sensor Nodes

There are presently various kinds of intelligent wireless sensors in use. Figure 1.2 demonstrates a general description of the hardware platform. Different sensor node features include size, battery consumption, power level, operating life, motion characteristics that include whether nodes are moving or stationary, position features, i.e. whether nodes are integrated with power supply.

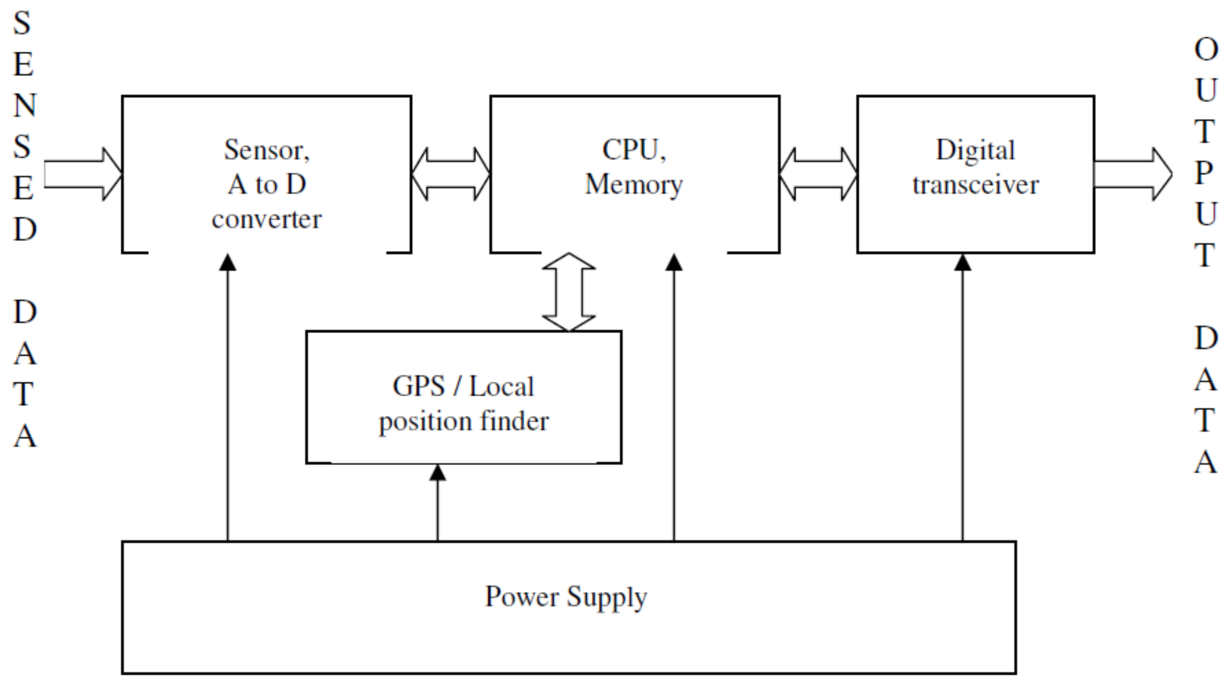

Figure 1.2: Sensor hardware platform

The various blocks shown in figure 1.2 have distinct capabilities as described below:

Sensor A to D converter:

Most of the naturally occurring data signal is analog or continuous in nature. This kind of data cannot be directly processed by the microcomputer installed inside the sensor nodes. So the first step, whenever some kind of data is received is to convert it into machine understandable form i.e. the digital form. This section performs this important task.

CPU/Memory:

The data received and converted into digital form is then sent to the central processing unit or the memory unit. Some sensor may require some kind of processing on the data to be performed whereas the other may just require to capture the sensed values in the memory locations. Depending on the requirement the sensor configurations and the corresponding hardware architecture varies.]

Digital Transceiver:

This module facilitates the transmission and reception of data packets to the other nodes or the base station. This module connects the sensor node with the entire network.

GPS/Location Finder:

Some of the sensor may require generating location data as well, thus an optional module can be present which generates the location using Global positioning System and can send this data to the central processing/memory unit.

Power Supply:

The power supply module provides required voltages and current to different parts of the sensor. Generally embedded devices are powered using dc voltage in the range of 3-6V.

Most of the sensor nodes consists of lithium ion battery to provide the required voltage for the operation. The power supply consists of voltage regulators and voltage dividers to convert to the necessary voltage and current ratings which can be required by different modules of the sensor nodes.

The other factors such as the limited capacity of single path reduces the available throughput. Secondly, considering the unreliable wireless links single path routing is not flexible to link failures, degrading the network performance. These factors single path routing cannot be considered effective technique.

1.4 Wireless Sensor Networks Routing:

The basic architecture of a typical wireless sensor node has been discussed in the previous section. Figure 1.1 shows the operation of sensor nodes. The data collected by the sensor nodes has to be transmitted to the base station which is called the sink node as well. The rules and protocols which define this movement of data packet from the sensor nodes to the base station constitute the term “Routing”. Routing is an important terminology when we are in the process of designing any wireless sensor-based network.

There are several ways in which data packets can be sent from the source i.e. sensor nodes to the sink i.e. the base station. The following diagram in figure 1.3 shows a broad classification of the routing algorithms.

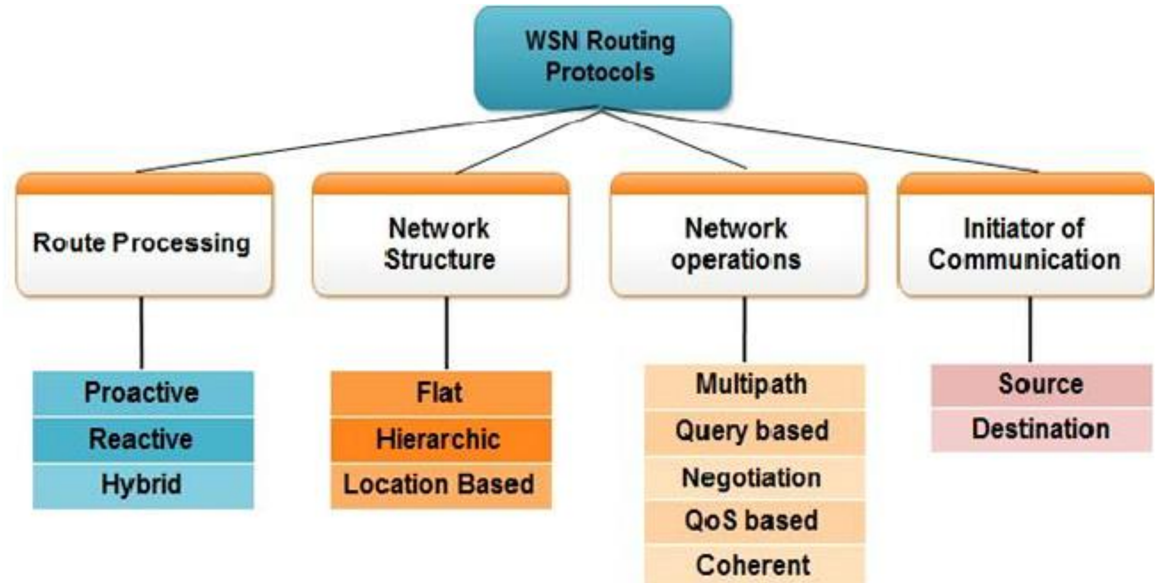

Figure 1.3: Routing Techniques in Wireless Sensor Network

1.4.1 Route Processing based routing protocols:

The route processing-based protocols are based on the method used for finding the best possible route for the packets to travel from source to destination. They are further classified as proactive, reactive and hybrid.

Proactive Routing:

In proactive routing, the routing table (path of data) is generated for every individual node and this table containing data path information of the entire network is periodically updated.

Reactive Routing:

In reactive routing, there is no need of generating routing table and the route is discovered instantly, as per the requirement. The source nodes generate a route discovery message for the network which is responded by the receiver nodes. Since no routing table is prepared thus there is no information of the packet transfer over the entire network and only the next hop neighbor is known and updated.

Hybrid Routing:

In hybrid routing, a combination of both the reactive routing and the proactive routing can be used as per the requirement.

1.4.2 Network Structure Based Routing:

The network structure is used to determine the routing of data packets in this type. The network structure defines the type of nodes and the characteristics they possess. Based on network structure, they can be flat routing, hierarchical routing or location-based routing.

Flat routing:

Flat routing refers to the set of protocols where the nodes are identical in behavior with no any kind of preferences and follow multi hop based communication. Data centric routing, SPIN and directed diffusion routing are some of the main routing protocols which fall under this category.

Hierarchical Based Routing:

The hierarchical based routing as the name suggests forms a tree like hierarchical structure to transmit data from source nodes to the sink nodes. This is also known as cluster head-based routing protocol or simply clustering protocol. It is most popular as well among all the Wireless sensor network routing techniques. Some of the popular techniques in this category are Low Energy Adaptive Cluster Head (LEACH) and its variants like SEP, DEEC, TEEN etc.

Location based:

In location-based routing, all the sensor nodes have location information of the other nodes in the network. The location co-ordinates of the destination node can be calculated by using relative location of nearby nodes to the source. Alternatively, radio signal strength indicator parameter can be used to identify the location coordinated of any node in the network. Global Positioning System or satellite location is also used to trace the location of the nodes. Geographic Adaptive Fidelity and Geographic and Energy Aware Routing are two popular routing techniques of this category.

1.4.3 Network Operation based Routing:

The network operation-based routing classifies the routing algorithms based on the functionality of the network. These routing classifications may contain routing from previous classes as well. Based on the difference in functionality the routing can be classified as below:

Multipath routing:

In multipath algorithms there can be more than one path between a particular source node and destination node. In case of the failure of the main path, these alternative paths can be utilized for successful completion of data transfer. Thus, this ensures a reliable communication link between the source and destination, Though, maintaining multiple path means maintaining additional routing tables which may increase the cost and computational complexity as well.

Query Based Routing:

As the name suggests these type of routing protocols are designed for facilitating the data transmission based on certain type of request or query. Every node maintains a table of queries and the corresponding messages or data which it has to send querying node(source), when that particular query is received by it. Directed diffusion qualifies to be classified as query-based routing protocol.

Negotiation based Routing:

In negotiation-based routing, before sending any actual data packet the negotiation messages are sent by the source nodes so as to reduce any duplicay in data transmission and effectively use the available resources. SPIN is an example of negotiation-based protocol for routing in wireless sensor network.

QoS Routing:

The Quality of Service based routing the quality of data packet being transferred is of utmost importance. There are certain quality metrics which are to be maintained while routing the data packets from source to sink. Some of major Qos metrics are energy, delay and bandwidth. SPEED and SAR are two major techniques which ensure highest QoS in wireless sensor routing.

Coherent Routing:

Coherent routing is defined on the basis of the type of processing done on the data being collected in the network, such as time stamping and data deduplication. Based on this, those routing protocols where the nodes perform certain level of preprocessing on data before sending it forward are called coherent routing protocols whereas there are certain protocols which may not perform any processing on the data, which may be termed as non-coherent routing protocols. The nodes which facilitate data processing in such case are called aggregators.

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1.5 Applications of Wireless Sensor Networks

Due to the variety of sensing capabilities incubated inside Wireless Sensor Networks, they can be utilized for a number of application areas. These instruments are capable of sensing in the setting the phenomenon of heat, acoustic, infrared, pressure, moisture, temperature, noise, etc. The following is the categorization of application fields for Wireless Sensor Networks:

- Military
- Environmental
- Health application
- Smart home
- Industrial

1.5.1 Military

On of the first and foremost application area of Wireless Sensor Networks has a been for military use. They have been used for autonomous army command, sending control instructions, for inter and intra based communications, ground surveillance, recognition and targeting systems in warfare. Easy deployment, low-cost and disposable features of sensor nodes make them very important in a multitude of important tasks such as monitoring of friendly forces, monitoring of machines and ammunition, biological and chemical detection and recognition of attacks, recognition of opposing forces, terrain, targeting as well as in damage assessment.

1.5.2 Environmental

They are also suitable for environmental applications such as animal movement surveillance, flood detection, forest fire detection, air pollution monitoring, etc. due to the deployment characteristics in inaccessible regions. In order to provide network longevity, some environmental applications including forest fire detection, solar cell equipped sensor nodes are being used.

1.5.3 Home Application

The sensor nodes are used to control home appliances such as refrigerators, microwave ovens, vacuum cleaners, furniture etc. Sensor nodes which are embedded on these appliances have connection to the Internet. Thus end user can control these appliances remotely over Internet connection.

1.5.4 Industrial

Industrial equipment monitoring and control, factory process control and industrial automation, material fatigue monitoring, product quality monitoring are some of the industry's application areas.

1.6 Motivation:

One of the most obvious challenges is the design of the energy-efficient routing strategy and has recently received considerable attention from the researchers. Since sensor nodes are run through non-rechargeable batteries in wireless sensor network applications with limited durability energy, innovative procedures have been required, which would end energy inefficient that reduce network life. There has been a lot of study of the optimal process and the protocol for network building. A large amount of energy is consumed in the various tasks conducted by sensor nodes such as sensing, processing, diffusion etc. All these operations are mainly responsible for the use of energy through contact with the local base station and, at the same time, one of the areas to be optimized in order to use the minimum of sensor resources. This increases the life cycle of network sensors and the whole network life. Routing protocols are important research areas, i.e. the way in which individual sensor nodes communicate.

The research motivation comes from the fact that the network lifetime can be improved by effectively choosing the way in which data packets are being transmitted from the source to the destination.

1.7 Wireless Sensor Network Characteristics:

In comparison with other wireless network types, the wireless sensor nets have different properties which affect network performance. These features, for example, node density, are unique to wireless networks in algorithms and protocols. As an example, the number of sensor nodes can be much larger than ad hoc networks and nodes are deployed. The number of sensor nodes can be very high. The basic features that affect network architecture and efficiency of wireless sensor networks are knots, node capabilities, node density, energy constraints In addition, node deaths often occur due to battery depletion or failure, leading to changes in topology.

1.8 Node Deployment

Depending on your application, the node deployment may be either deterministic or self-organizing. Nodes are positioned at pre-determined locations in a deterministic way and data routing is carried out over pre-determined paths. After initial deployment it is also possible to add additional sensor nodes for retrieval or network support. On the other hand, nodes are randomly distributed around the application area in the self-organized wireless sensor networks to form an ad hoc network.

1.8.1 Topology of Network

The standard IEEE 802.15.4 supports two types of the topologies as shown in Figure 2.1. In star topology, there must be at least one FFD as PAN coordinator to control devices in its respective PAN. The coordinator node is responsible for the controlling the PAN and communicating to the other PAN coordinators. In peer-to-peer topology there must be at least one PAN coordinator and nodes have to be in the communication ranges of one another to establish a link. In such a network every node acts as a router and supports multi-hop routing. This kind of topology is used in the mesh networks which have complex topology.

1.8.2 Power Consumptions

A sensor node is a battery-limited microelectronic system. Network life depends on the sensor node'S battery life, as node batteries that are spread through inaccessible applications can not be replaced literally. For example, two AA batteries (2.1-3.6V DC) are supplied by a Telos mote, which has CC2420 NIC integrated. For sensor networks the energy efficient management of power is therefore highly critical.

For the design of a sensor node, dynamic power management is a major requirement. This extends the lifetime of a sensor node to an event driven power consumption. The sensor nodes are power consuming at different rates for their states like idle, sleep, receiving, transmitting, etc. In view of the data sheet of the TI CC2420 NIC, currents are receiving and transmitting far superior to idle current and sleep current as shown in Table 1.1. IEEE 802.15.4 compliant devices have sleep modes and spend much of their time on sleep, even if a packet is received or passed on.

Table 1.1: Power Consumption of TI CC2420 NIC

State	Value	Unit
Voltage Regulator Off	0.02	μA
Power Down	20	μA
Idle	426	μA
Receive	18.8	mA
Transmit	8.5 – 17.4	mA

1.8.3 Heterogeneous Elements

The IEEE 802.15.4 distinguishes two separate computer types with various functions. In contrast, RFD nodes have very simple tasks like communicating with and sensing a coordinator as shown in Figure 1.1. FFD node can function as a PAN coordinator, communication with other coordinators or simple devices.

Such nodes are often integrated into vehicles like UAVs, busses or robots in addition to their mobility and do not suffer from energy restrictions. These mobile nodes have rich device resources in comparison with sensor nodes.

1.9 Objective of the Research:

This thesis focuses on adaptive energy conservation and optimization in the wireless sensor's networks. As mentioned above, the wireless sensor nodes depend on a fixed energy source i.e. battery, the energy and power consumption is so critical in such applications. Thus, the primary objective of this research work is to delve into the area of energy conservation thus improving the network lifetime. The key objectives are as mentioned below:

1. To study the various low energy-based routing protocols suggested by earlier researches.
2. To implement a novel protocol for wireless sensor network routing, which will be based on LEACH protocol.
3. To compare the designed protocol with the existing routing protocols in terms of network lifetime, alive nodes, dead nodes etc.

Chapter 1 provides an overview of the wireless sensor networks and their different terminologies, Chapter 4 provides a detailed description of the system architecture used in the implementation process, chapter 4 gives a description of implementation details and simulation result, and the conclusion and future work are contained in Chapter 5.

CHAPTER 2

LITERATURE SURVEY

Now a days the effectiveness of Wireless Sensor Network cannot be ignored. The vast diversity of sensor nodes provides WSNs with a wide range of applications in military, industry, security and environmental research as discussed in previous chapter. The biggest challenge in WSN is the limited battery energy as these are deployed in areas where it is not feasible to replace the battery. So it is an active area of research and there are many existing routing protocols. In this Chapter we provide a survey of literature on some existing widely used wireless sensor routing protocol in WSNs from which clustering based routing protocols will be focused mainly.

2.1 Some Existing Widely Used Wireless Sensor Routing Protocols

Recent advances in WSNs have lead to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration.In Direct

Communication Protocol ,each sensor node transmits information directly to the base station, regardless of distance. As a result, the nodes furthest from the Base are the ones to die first. On the other hand, in case of Minimum Transmission Energy routing protocol data is transmitted through intermediate nodes. Thus each node acts as a router for other nodes' data in addition to sensing the environment. Nodes closest to the Base are the first to die in MTE routing. So far, cluster-based technique is one of the approach which successfully increases the lifetime and stability of whole sensor networks.

Table 1: categories of routing protocols

Calegories	**Representative protocols**
Data Centric Protocols	Flooding And Gossiping, SPIN, Direct Diffusion, Rumor Routing, Gradient Based Routing, Energy-Aware Routing, CADR COUGAR & ACQUIRE
Hierarchical Protocols	LEACH, PEGASIS, TEEN, APTEEN
Location Based Protocols	MECN&SMECN, GAF & GEAR
Network Flow &Qos Aware Protocols	Maximum Lifetime Energy Routing, Maximum Lifetime Data Gathering, Maximum Cost Forwording, SAR &SPEED

Routing protocols subdevided into protocols with network structure and protocol operation and both are devided in many protocols that are showing in fig 2.1. for over work we studied about herarchical routing protocols.

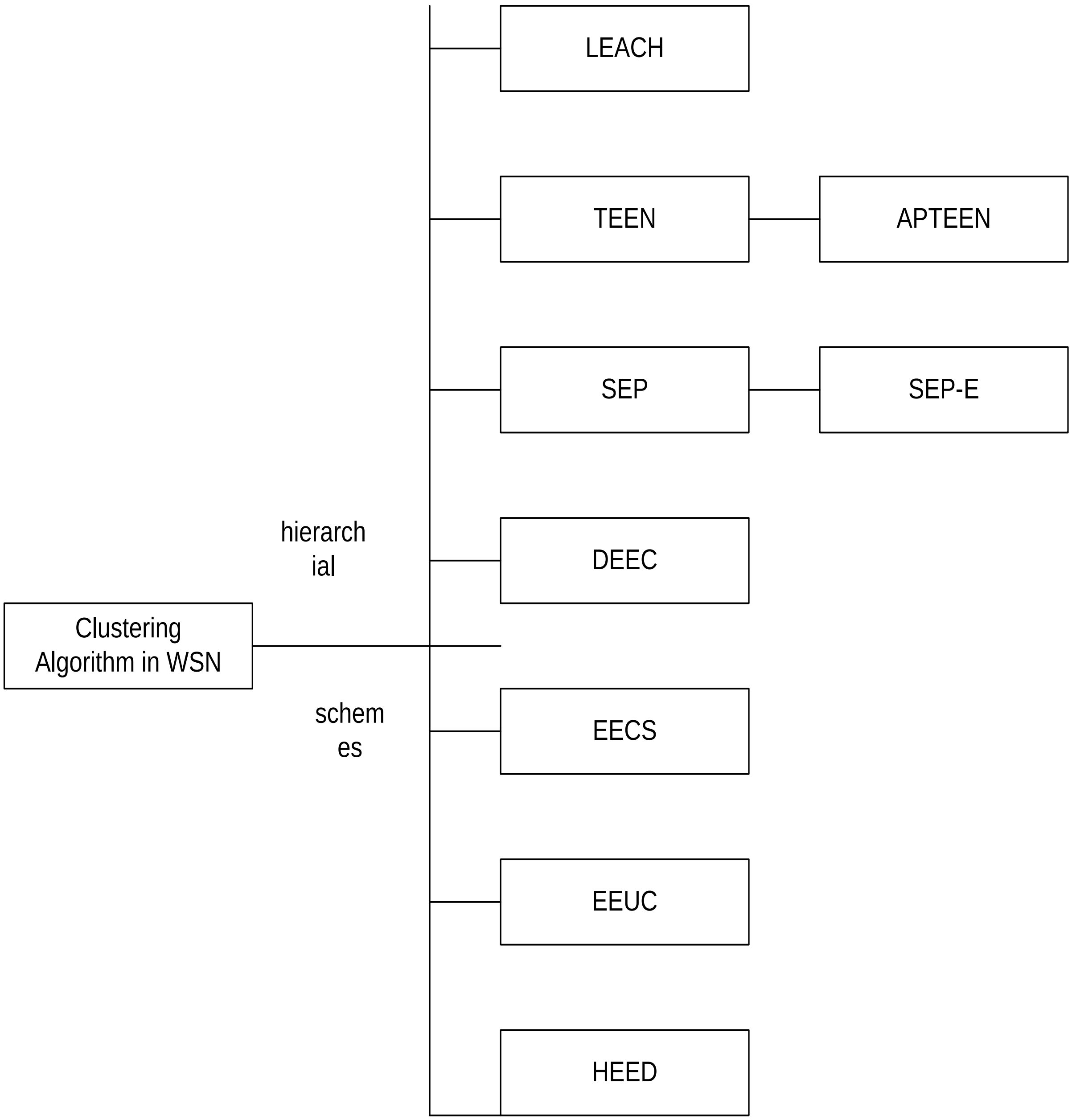

Fig 2.1: Classification of widely used clustering schemes in WSN

2.2.1 LEACH

W. R. Heinzelman, A. P. Chandrakasan and H. Balakrishnan [5] stated Low Energy Adaptive Clustering Hierarchy (LEACH) protocol in 2000. It 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 strength of the signal and use local cluster heads as routers to the BS. This helps to 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 10 percent of the total number of nodes. In order to balance energy of nodes Cluster heads change randomly over time . Node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold:

$$
\begin{aligned}
T(n) &= \frac{P}{1 - P * (\frac{1}{P})}, \quad \mathrm{n} \in \mathrm{G} \\
&= 0, \qquad \mathrm{Otherwise}
\end{aligned}
$$

Where p is the desired percentage of cluster heads (e.g. 0.1), r is the current round and G is the set of nodes that have not been cluster heads in the last 1/p rounds. However the limitations of Leach protocol are that it uses single-hop routing within cluster and thus not applicable to networks deployed in large regions, dynamic clustering brings extra overhead, assumes all nodes can transmit with enough power to reach BS, if necessary (for example , elected as CHs), Each node should support both TDMA and CDMA. LEACH is only effective for homogeneous network . Consequently, a number of enhancements to the conventional LEACH routing protocol have been proposed and is summarized. In Centralized LEACH (LEACH-C) [6] location of the nodes is sent to the BS, which then selects CHs for each round. No. of CHs is fixed to a predetermined value. The BS utilizes global knowledge of the network to produce better clusters that require less energy for data transmission. Balanced-LEACH protocol (LEACH-B) [6] is a adaptive strategy is designed whereby each node chooses its CH evaluating the energy dissipated in the complete path between itself and the final receiver, passing by the CH. It performs well when the final receive is closer to the sensors. In Two-Level LEACH (TL-LEACH) [7] two level hierarchy of CHs are formed. The secondary CH collects data from the cluster members and relays the data to the base station through a primary CH that lies between it and the BS. Here better distribution of the energy load among the sensors in dense networks. In Multihop Low energy adaptive clustering hierarchy (MH-LEACH) [8] the CHs away from the sink, sends data to the sink using the other CHs as relay stations. It is improved throughput. In Advanced-solar aware- Low energy adaptive clustering hierarchy protocol (A -s LEACH) [9] all nodes are considered to be solar powered having battery power as backup, where CHs initially selected by BS, chooses the next CHs after a certain time called round. Here nhanced data aggregation by FIFO priority scheme and collision minimized non-persistant Carrier Sense Multiple Access (CSMA).

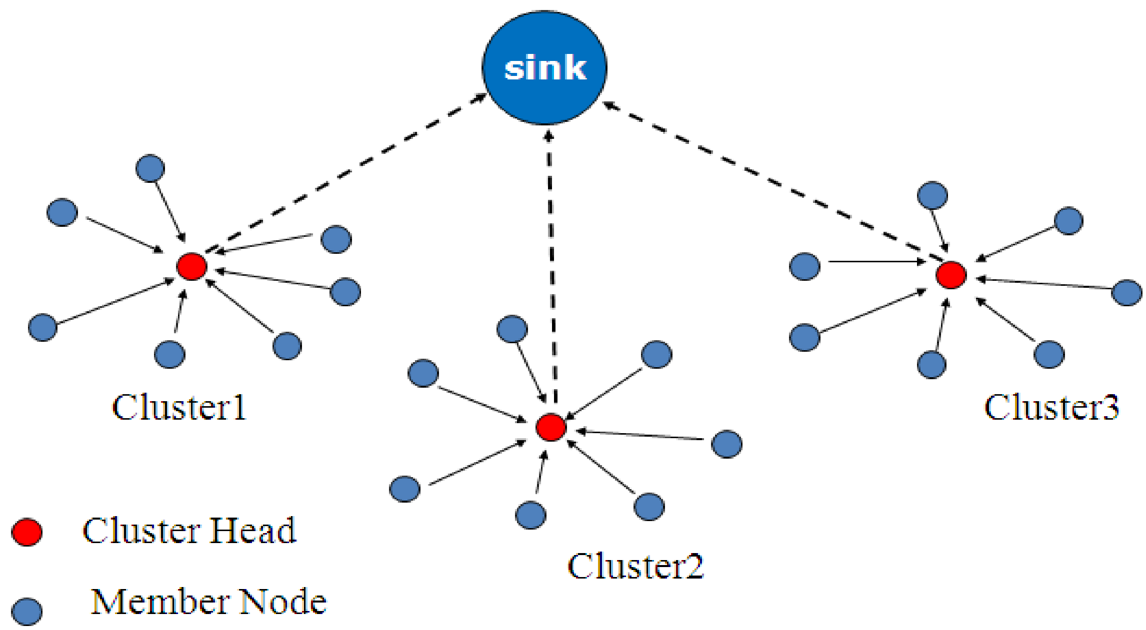

Figure 2.2 LEACH Protocol

2.2 PEGASIS

S. Lindsey and C. Raghavendra [10] proposed Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol in 2002. It is an improved version of LEACH protocol. Instead of forming clusters, it is based on forming chains of sensor nodes. One node is responsible for routing the aggregated data to the Base. Each node aggregates the collected data with its own data and then passes the aggregated data to the next ring.The difference from LEACH is to employ multi-hop transmission and selecting only one node to transmit the data to the sink or base station. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data aggregationis employed. PEGASIS out performs the LEACH. However more delay is introduced for distant nodes, especially for large networks, where single leader can be a bottleneck.

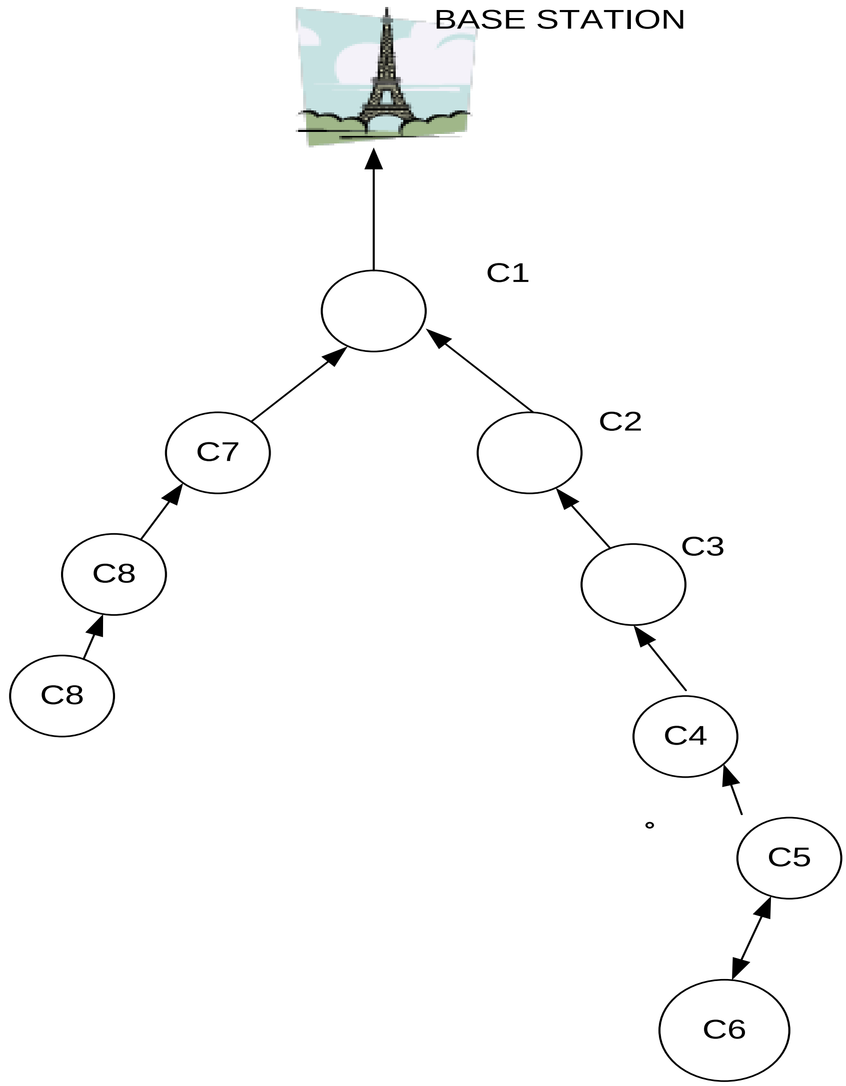

Figure 2.3: PEGASIS

2.3 TEEN

In 2001, A. Manjeshwar and D. P. Agarwal [11] introduced Threshold sensitive Energy Effcient sensor Network Protocol (TEEN) protocol. Closer nodes form clusters, with cluster heads to transmit the collected data to one upper layer. Forming the clusters, cluster heads broadcast two threshold values.

***Hard Threshold (*HT)**:** it is less possible value of an attribute to trigger a sensor node. Hard threshold allow the nodes to transmit the event, if the event occurs in the range of interest. Therefore a significant reduction of the transmission delay occurs.

***Soft Threshold (*ST)**:** Soft threshold is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. The nodes sense their environment continuously to the environment. The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data. The sensed value is stored in an internal variable in the node, which is called the *sensed value (SV)*. The nodes will next transmit data in the current cluster period, if *both* the following conditions are true:

1. The current value of the sensed attribute is must be greater than the hard threshold.

2. The current value of the sensed attribute differs from *SV* by an amount equal to or greater than the soft threshold.

Whenever a node transmits data to the base station, *SV* is set equal to the current value of the sensed attribute. Thus, the hard threshold value which is taken by user is tried to reduce the number of transmissions by allowing the nodes to transmit only if the sensed attribute is in the range of interest for transmitting range value. The soft threshold further reduces the number of transmissions by eliminating all the transmissions which might have otherwise occurred when there is little or no change in the sensed attribute once the hard threshold.

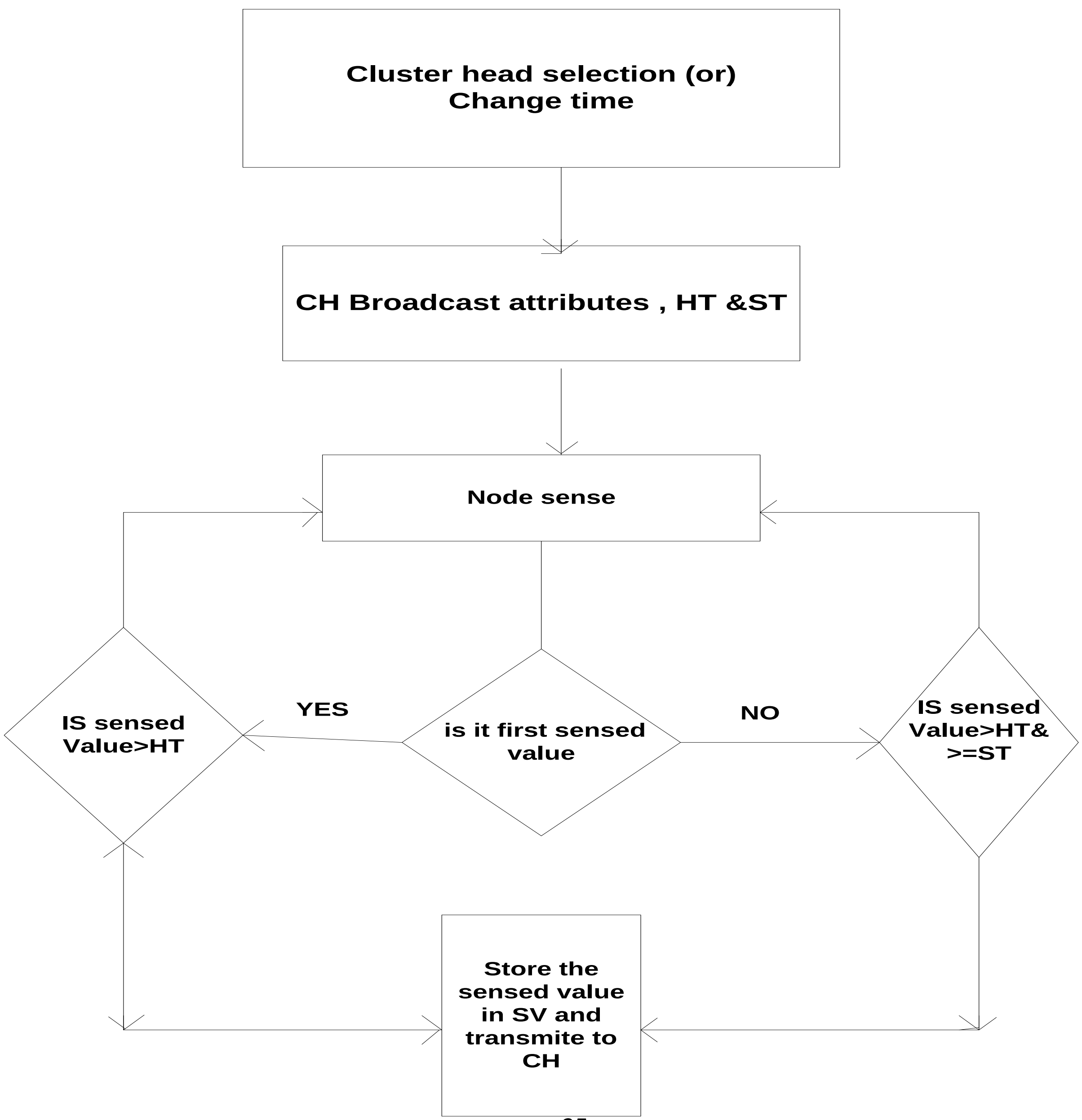

Figure 2.4: Flow chart of TEEN

Important Features

The main features of this scheme are as follows:

1. Time critical data arrives the user instantaneously. So, this scheme is useful for time critical data sensing applications.

2. Message transmission consumes more energy than data sensing. The energy consumption in this scheme can potentially be less than in the proactive network.

3. The soft threshold varies it depends on sensed attribute and the target application.

4. A small value of the soft threshold gives a more accurate picture of the network, so the user can control the trade-off between energy efficiency and accuracy.

5. The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate; the user will not get any data from the network at all and will not come to know even if all the nodes die. Thus, this scheme is not well suited for applications where the user needs to get data on a regular basis. Another possible problem with this scheme is that a practical implementation would have to ensure that there are no collisions in the cluster.

Time division multiple access (TDMA) scheduling of the nodes can be used to avoid above problem. This will however introduce a delay in the reporting of the time-critical data. Code division multiple access (CDMA) is another possible solution to this problem.

2.4 APTEEN

The protocol is an extension of TEEN aiming to capture both time-critical events and periodic data collections. The network architecture is same as TEEN. According to energy dissipation and lifetime of network, TEEN gives better performance than LEACH and APTEEN, because of the decreased number of transmissions. The main drawbacks of TEEN and APTEEN are overhead and complexity of forming clusters in multiple levels, implementing threshold-based functions and dealing with attribute based naming of queries.

2.5 SEP

In 2004, G. Smaragdakis, I. Matta and A. Bestavros introduced Stable Election Protocol (SEP) [13]. This protocol is an advancement of LEACH. Cluster head election is randomly selected and distribution is based upon the fraction of energy of each node, which assures a uniform use of the energy. In this protocol, two types of nodes (two tier in-clustering) and two level hierarchies were considered. CHs selecting probability for normal nodes is pnrm=popt/(1+m.α) and for advanced nodes

$$p_{adv}=p_{opt}.(1+\alpha)/(1+m.\alpha),$$

where popt is the optimal probability of each node to become CH. The idea is that the advance nodes have to become the CHs more often than normal nodes. SEP gives better result as the value of α and m will increase.SEP maintains the constraints of well-balanced energy consumption.

As initially, advanced nodes have to become the CHs more often than normal nodes. Thus, SEP produces longer stability region by using the extra energy of more powerful nodes. But the main drawback of SEP method is that the election of the cluster heads among the two type of nodes is not dynamic. But the possibility in SEP is that after certain rounds an advanced node might become normal node due to more energy consumption. In such conditions, SEP selects low energy node as a maximum probability of being cluster head as SEP is only aware of nodes initial energy.

2.6 E-SEP

The enhancement of SEP, Femi A. Aderohunmu and Jeremiah D. Deng[14] introduced E-SEP in the year of 2009.E-SEP considers three types of nodes, normal nodes, intermediate nodes and advance nodes. Where, advance nodes are in a fraction of total nodes with an additional energy as in SEP and a fraction of nodes with some extra energy greater than normal nodes and less than advance nodes, called intermediate nodes, while rest of the nodes are normal nodes. As in SEP, the initial energy for normal nodes is Eo, and for advanced nodes is $(1+\alpha).E0$. E-SEP added another set of initial energy nodes i.e. Eint as $(1+\beta)*Eo$, where $\beta=\alpha/2$. Like SEP, in E-SEP CHs are selected depend on probability of each type of node. However, energy dissipation is controlled to some extent due to three levels of heterogeneity. ESEP have drawbacks similar as SEP. For selecting CHs it also set the probability based on nodes initial energy. E-SEP also does not consider residual energy of nodes. Other extension of SEP protocols are ASEP-E [15], Z-SEP [16], T-SEP [17] and H-SEP [18]. In ASEP-E, four types of nodes have been used for assigning the probability of each type of nodes. The new type of nodes are referred to `super advance nodes' whose initial energy is

$$(1+ \beta) *Eo, \text{ where } \beta = \alpha / 4.$$

Z-SEP is zone based clustering algorithm where the advance nodes only have the probability to become a cluster head. Drawbacks of Z-SEP are, nodes cannot be deployed randomly and only advance nodes are selected as a cluster head. As a result advance nodes are died soon. As in T-SEP the CHs selection is done based on threshold value, it decreases the throughput due to threshold sensitivity.

2.7 DEEC

In 2006, Q. Li, Z. Qingxin and W. Mingwen[19] introduced Distributed Energy Efficient Clustering Protocol (DEEC) protocol. This protocol is a cluster based scheme for multi level and two level energy heterogeneous WSNs. The nodes with high initial and residual energy have more chances to become the cluster heads as compared to nodes having low energy. The main disadvantage of DEEC is advanced nodes are always penalized, particularly when their residual energy reduced and become in the range of the normal nodes.

2.8 EECS

In 2005, M. Ye, C. Li, G. Chen and J. Wu[20] introduced Energy Efficient Clustering Scheme (EECS) protocol. It is novel clustering scheme for periodical data gathering applications for wireless sensor networks. The competition process is localized without iteration. Further in the cluster formation phase, a novel approach is introduced to balance the load among all cluster heads.

2.9 HEED

In 2004 ,O Younis, S Fahmy introduced HEED : A hybrid, energy-efficient, distributed clustering approach [21]. HEED is a multi-hop clustering algorithm for WSNs, with a focus on efficient clustering by proper selection of cluster-heads based on the physical distance between nodes.Moreover HEED aims to provide evenly distributed CHs throughout the network. CHs sends the aggregated data to the BS in a multi-hop fashion rather than single-hop fashion of LEACH. Similar to LEACH, the performance of clustering in each round imposes significant overhead in the network. This overhead causes noticeable energy dissipation which results in decreasing the network lifetime.The use of tentative CHs that do not become final CHs leave some uncovered nodes. As per HEED implementation, these nodes are forced to become a CH and these forced CHs may be in range of other CHs or may not have no member associated with them.

2.10 EEUC

In 2005, C. Li, M. Ye, G. Chen and J. Wu[22] introduced an energy-efficient unequal clustering mechanism for WSNs.EEUC is designed for periodic data gathering applications in WSN. According to this ,the nodes in one region compete to become CH in such a way that the node's competition range decreases as its distance to the base station decrease. Energy consumed by cluster heads per round in EEUC much lower than that of LEACH standard but similar to HEED protocol.

CHAPTER 3

METHODOLOGY

The concept of network lifetime is one of the most important area of interest for the research in wireless sensor networks. Nodes deployment is the first step in establishing the sensor network with the battery powered and randomly installed sensor nodes in the target area. One of the big tasks in the wireless sensor networks is to increase the network lifespan to optimize energy usage. Once the sensor nodes are uniformly deployed, the sensor nodes near the sink transmit their own data and the data gathered from the sink by other nodes in a multi-hop manner and individual sensors cannot execute manually after the deployment sensor network. Within the nearness of the base station the sensor nodes absorb more energy than the base station node and die faster. In turn, when 90% of nodes are alive with ample resources unused, the network will disconnect. In this research we investigate and seek to eradicate the question of energy vacuum. It is required to analyze the energy imbalance in these protocols, and attention has been given to the information about the existing sleep and wake processes of nodes in order to boost the network 's lifespan.

All the nodes are not having data which to be transmitted to the base station. As such unnecessarily energy is dissipated in establishing the radio link with the cluster head for sending essentially no data packets. If this scenario is taken into consideration, it is possible to reduce the energy dissipation and efficient usage of the available battery life of the sensor nodes. In this research work, this inactivity of the sensor nodes has been taken into consideration while designing the network model and while deciding the participation of the nodes in the routing process. In this chapter the various steps taken to implement the proposed method has been discussed.

3.1 Free Space Signal Propagation Model:

The distance between transmitter device and receiver device antennas is an important factor to determine the received power of a signal. The electromagnetic wave theory states that the power is an inverse function of this distance. Another important realization is that there is a direct communication between a transmitter device and a receiver device known as the line of sight, as given the Free Space Model devised by Friis. The recipient may not however be in the transmitter's line of sight, always. As a consequence, the signal bounces off the objects in the system and at different times hits the receiver from various directions. The receiver receives the overlay from various paths of these many copies of the transmitted signal. This is regarded as a multi-way fading that can be modeled roughly as a power law function that can be used to separate transmitter and receiver from two-raying model. When each signal travels from the transmitter to the receiver, variations in attenuation, delay and phase shift can occur. The signal energy received at the receiver may be either constructive or destructive, amplified or attenuated.

Let “Pt” is the power delivered by the transmitter antenna in watt. For a moment assuming that the transmitter antenna is omnidirectional, lossless, then the received power density (w/m^2) at receiver end at a distance d from the transmitter antenna is

$$S_r = \frac{Power}{Area} = \frac{P_t}{4\pi d^2} \quad \text{W/m}^2 \qquad (3.1)$$

But any practical antenna has its own directivity. Here the directive gains of transmitter and receiver antenna are respectively Gt and Gr where both Gt and Gr are less than unity. The power density received actually because of directive gain of transmitting antenna is

$$S_r' = \text{power density} \times \text{Gain} = \frac{P_t}{4\pi d^2} \times G_t \tag{3.2}$$

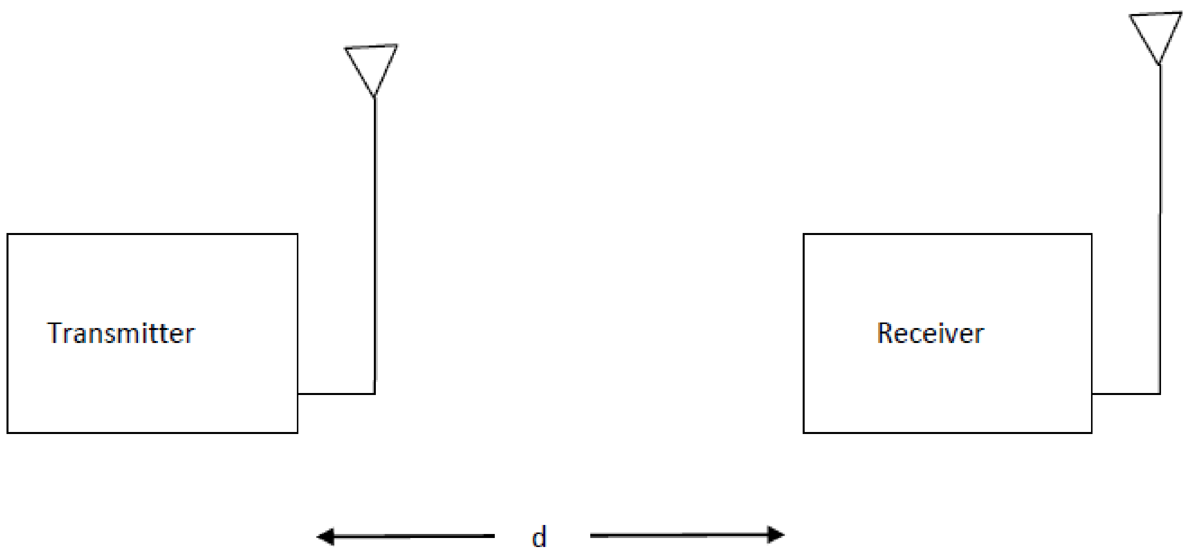

Figure 3.1: Friis Radio model

Friis free space loss and multi-path loss are both dependent on the distance between the nodes and configuration of the transmitter amplifier.

As discussed in the literature review section, the energy varies in proportion of square of the distance for relatively small distances between transmitter and receiver, whereas when the distance becomes relatively large, the energy dissipation varies in proportion to quadratic factor i.e. d^4. The cutoff distance which is used to determine the power loss is known as crossover distance and is defined as:

$$d_{crossover} = \sqrt{\frac{\epsilon fs}{\epsilon mp}} \tag{3.3}$$

where ϵfs, is free space loss and ϵmp is the multi path loss.

3.2 Clustering Process:

Clustering hundreds of nodes into many smaller, controllable groups may eventually increase network performance. Dividing the network into several clusters decreases traffic and energy usage within the network. As discussed earlier, clustering provides a mechanism for reducing communication between nodes and thus minimizing energy consumption. Research has shown that clustering increases the overall efficiency of wireless sensor networks such as overhead connectivity and longevity. If a sensor needs to reduce its power demand, its data packets should be sent first to the cluster heads rather than to the sink. Sensors are classified according to their energy levels, sensed data types, proximity or several other parameters. There are plenty of proposed effective ways to select cluster heads. As energy efficiency is very critical for the lifetime of the network, clustering thus becomes crucial. In the control of energy consumption, data propagation techniques is also extremely successful. There are two separate ways to send a packet to the sink node. First, node can choose to send its packet directly to the sink in a hop mode that demands more energy. Second, a node is able to choose one of its neighbors for multi-hop relaying its packets to the sink. When the second solution is used, the power consumption is lower, as the distance between two nodes is smaller. When the distance from a node and sink is increased, energy consumption increases incrementally.

Various methods are used for selecting cluster heads such as selecting nodes closer to the base station, randomly choosing nodes, or selecting nodes with the highest or lowest parameters than neighbors where parameters which include: residual energy level, neighbor number, packet count, sensed value, single identifier, etc. However, it is not always efficient to use simple clustering algorithms. When simple clustering algorithms like selecting nodes with the lowest or highest number are used, the same nodes are often chosen as cluster heads. As a consequence, these selected nodes drain easily. In order to minimize energy consumption, the optimized selection of cluster heads is important to distribute the cargo evenly between other nodes. Clustering may also be carried out on a single level, which is the most common process, or multi-level clusters, which establish clusters within a cluster, also known as hierarchical clustering. Data collection and its aggregation, is also commonly used in clustering, as data from member nodes is collected and sent in a single packet to the plinth to reduce traffic in the network. It also relates to clustering. If two packets from two different source nodes are received by a cluster head node, the incoming packets and the average readings can be calculated to send the final value as one single data packet. Another alternative to combine data for a sensor node is to merge two separate readings into a single packet with the final packet. Both approaches rising energy consumption and data traffic in the network. Data collection can be done regularly, where nodes send their sensed data during defined intervals or events, where nodes send their fashion or events guided, where nodes only transmit their sensed data when the sink is sensed and alerted by a significant event. The most common approaches to building clusters are a centralized and distributed approach. For large-scale networks, a distributed approach is more popular as centralized solutions require knowledge of Network Topology and time and energy usage.

For the proposed algorithm, a distributed approach is better because the proposed algorithm has been considered to be adaptable to large networks. The nodes also determine whether they will be the group head of clusters or one of the group members, based on information from their neighbors and on a large number of criteria coded in the algorithms we are proposing. The top-down approach and the bottom-up approach is two alternative ways to build clusters and clusters. In top-down approach root selects its neighbors and they form their own cluster heads. In forming clusters and clusters, this approach provides more power saving.

3.3 Problem Statement

There are a number of drawbacks of LEACH based protocol could be briefed into following basic problems.

• The first problem deals with the inaccurate choice of the cluster head, which not takes into account the amount of residual energy.

• The second problem instigated by the inequitable distribution of sensor nodes, having considered the homogenous nature of nodes. The energy consumption of the sensor nodes far away from the sensor nodes die away quickly, thus extra energy is required.

3.4 Solution Approach

A study of the impact of heterogeneity in terms of node energy is undergone in this research work. It is assumed that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network—this is the case of heterogeneous sensor networks. This research is motivated by the fact that there are a lot of applications that would highly benefit from understanding the impact of such heterogeneity. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy. Another advancement is modifying the selection parameter for cluster head selection by taking account of the residual energy of the nodes, while deciding the cluster head.

3.5 Proposed Algorithm

Setup Phase:

The setup phase is the primitive phase in deploying the network. As, we are simulating the actual network on a virtual software environment, we define the various characteristics which are possible for a network, based on the mathematical and physical modeling of the network. The various properties of the network like the field area, the number of nodes, various kinds of sensor energies are all need to be defined.

- Node Area- 100x100
- Base Station Position: 100,100
- Node Positioning: Randomly

The algorithm for node positioning is as below:

For i= 1 $\rightarrow$ 100

X(i) = rand(1,1)*100;

Y(i)= rand(1,1)*100;

Two types of heterogeneous node have been considered here based on their energy content viz. normal and advanced. The normal and advanced nodes are positioned randomly and their respective energies are assigned to them. The algorithm for setting up the characteristics of all three types of nodes is as shown below:

temp_rnd0=i

Initially there are no cluster heads only nodes

Random Election of Normal Nodes

if (temp_rnd0>=m*n+1)

```
      S.E= E0
      S(i).ENERGY=0
   end
Random Election of Advanced Nodes
   if (temp_rnd0<m*n+1)
     S(i).E=Eo*(1+a)
      S(i). ENERGY=1;
   end
```

Steady State Phase:

Once the network becomes operational the sensors become active and start sensing. The hierarchical architecture starts with finding the cluster heads and associating the non-cluster heads with the cluster heads.

Cluster head Selection:

The optimal probability of various categories of nodes i.e. normal and advanced, to be elected as cluster heads is dependent on selection probabilities given by below equations:

$$Pnormal=(p/(1+a*m)) \quad (3.4)$$

$$Padv= (p*(1+a)/(1+a*m)) \quad (3.5)$$

where, p is selection probability, a is additional energy factor for advanced nodes m is proportion of advanced nodes to total number of nodes n with energy more than rest of nodes.

To ensure that CH selection is done in the same way as has been assumed, we have taken another parameter into consideration, which is threshold level. Each node generates randomly a number inclusive of 0 and 1, if generated value is less than threshold then this node becomes CH For all these type of nodes we have different formulas for the calculation of threshold depending on their probabilities, which are given below [1]:

$$Tnrm = \frac{pnrm}{1-pnrm(r.mod\left(\frac{1}{pnrm}\right))} \quad \text{if } n_{nrm} \in G'$$

0 otherwise

$$Tadv = \frac{padv}{1-padv(r.mod\left(\frac{1}{padv}\right))} \quad \text{if } n_{adv} \in G''$$

0 otherwise (3.5)

Where G’, G’’ represents the number of nodes from normal and advanced nodes who have not earlier become cluster heads.

The optimal probability of selection as a cluster head is based on distance and energy values calculated using below equations.

distance=sqrt((S(i).x-(S(n+1).x)) ^2 + (S(i). y-(S(n+1). y)) ^2) (3.6)

The energy dissipation is calculated as per the given conditions:

if (distance>do)

S(i).E=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*($distance^4$) (3.7)

if (distance<=do)

S(i).E=S(i).E- ((ETX+EDA)*(4000) + Emp*4000*($distance^2$) (3.8)

CHAPTER 4

RESULT AND ANALYSIS

The implementation of the proposed algorithm has been done in MATLAB software using its various toolboxes, MATLAB graphics functions and basic programming structure of the software. MATLAB is a high-end technical programming language which is used extensively in industrial and academic research. It contains an easy to use programming language which is pseudo code or algorithm based. It means that the algorithm or pseudo code easily converts into a workable program. The toolboxes give an added advantage for programmers. The toolbox is a package or collection of built in domain specific functions which are ready to use. There are about more than hundred toolboxes in MATLAB which makes the task of scientists, researchers and students' task easier working in these domains.

4.1 Simulation Parameters

The implementation results and simulation are discussed and analyzed in detail. Network software setup requires certain parameters derived from the radio model of a typical Wireless Sensor network architecture as has been described in Chapter 3. The various equations defining the energy dissipation process in the wireless sensor network has been implemented in the software. The various network modelling parameters with their values are shown in the Table 4.1. For this simulation the network area is 200mx200m. The base station is placed at location x=100, y=100 in the network area. The division shows the different cluster formation in the network area. The number of nodes is taken to be 200. The network is simulated for 2500 rounds. The rounds are equivalent to a certain time scale. After every round the energy dissipation factor from different sources is accumulated to calculate the average energy left in each node.

Table 4.1: Simulation Parameters

Parameters	**Values**
Network Area	200m
Crossover distance, d0	sqrt(E_{fs}/E_{mp})
Electronics circuitry energy E_{elec}	50 nJ/bit
Energy consumed for LOS E_{fs}	10 pJ/bit/m_2
Energy loss for multipath, Emp	0.0013 pJ/bit/m_4
Data Aggregation Energy, EDA	5 nJ/bit/signal
Initial Energy, E0	0.5 J
Selection Probability	0.1

The selection probability for a node to become a cluster head is taken as 0.1, i.e. out of all the available nodes 10 percent can become cluster heads.

4.2 Tools Used

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. The name MATLAB stands for Matrix Laboratory. MATLAB was originally made to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science

Key Features:

- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration, and solving ordinary differential equations**.**
- High-level language for numerical computation, visualization, and application development.
- Interactive environment for iterative exploration, design, and problem solving.
- Built-in graphics for visualizing data and tools for creating custom plots.
- Tools for building applications with custom graphical interfaces.
- Functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET, and Microsoft Excel.
- Development tools for improving code quality and maintainability and maximizing performance.

Architecture of MATLAB system:

The MATLAB system consists of five main parts:

Development Environment:

It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path. This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces.

The MATLAB Mathematical Function Library:

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

The MATLAB Language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

Graphics:

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on our MATLAB applications.

The MATLAB Application Program Interface:

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

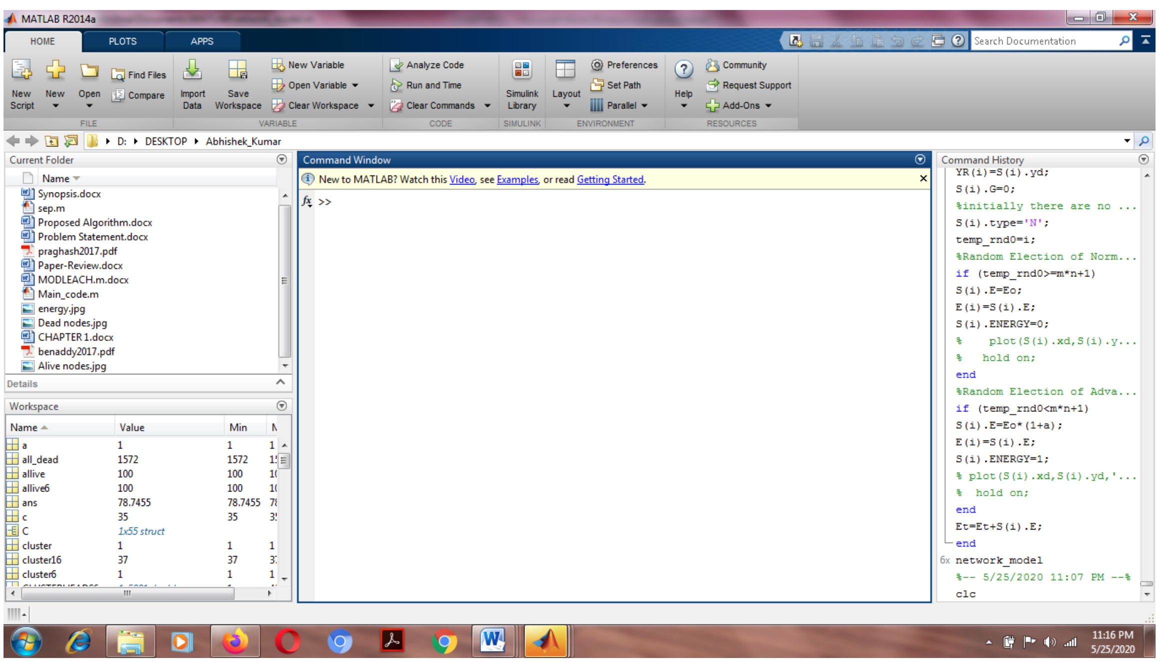

Figure 4.1: MATLAB interface

Strengths:

- MATLAB combine nicely calculation and graphic plotting.
- MATLAB is relatively easy to learn.
- MATLAB may behave *as* a calculator or as a programming language .
- MATLAB is optimized to be relatively fast when performing matrix operations.
- MATLAB does have some object-oriented elements.
- MATLAB is interpreted (not compiled), errors are easy to fix.

Weaknesses

- MATLAB is an interpreted language, slower than a compiled language such as C++
- MATLAB is not a *general-purpose* programming language such as C, C++, or FORTRAN
- MATLAB is designed for scientific computing, and is not well suitable for other application
- MATLAB commands are specific for MATLAB usage.
- Most of them do not have a direct equivalent with other programming language commands

4.3: Simulation Results:

The simulation results have been plotted as graphs between various parameters obtained and the number of rounds as shown in below figures.

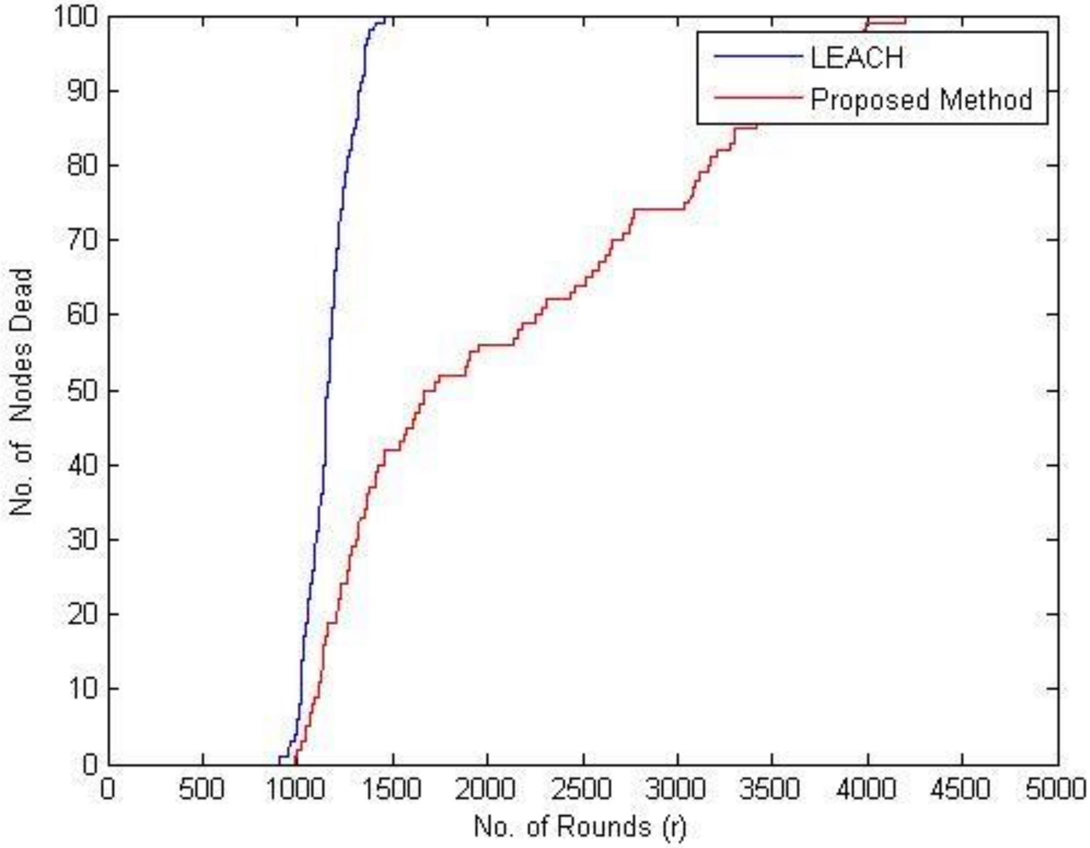

Figure 4.1: Number of Dead nodes vs rounds

The above figure 4.2 shows the comparison of the proposed protocol proposed in this research work with that of the LEACH protocol. As shown from the figure 4.2 the proposed method has a considerable improvement in terms of nodes getting inactive or dead. The first dead node in the LEACH protocol under similar simulation parameters and network parameters occurs at around 949 rounds whereas in the proposed algorithm the first dead node occurs at around 1692 rounds for advanced nodes and 927 for normal nodes.. This is a notable improvement in the lifetime of the network. Similarly, the nodes die out completely at around 1572 rounds in LEACH protocol whereas in the proposed protocol the network dies out at round number 4138. This further affirms the effectiveness of the proposed protocol. The below figure shows the number of alive nodes plotted against the number of rounds.

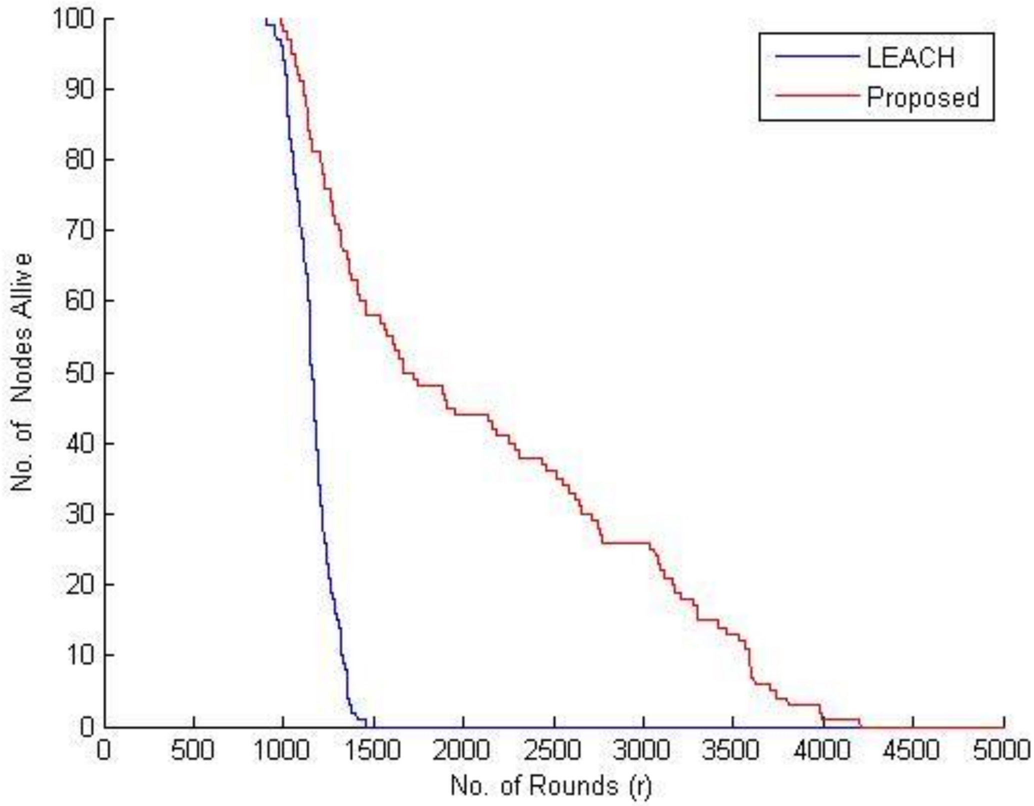

Figure 4.2: Number of Alive Nodes

Figure 4.2 shows the graphical plotting of number of nodes alive after each round. It is almost reciprocal to the graph of dead nodes. As is visible from the graph, there is considerable improvement in the number of alive nodes as compared to LEACH protocol.

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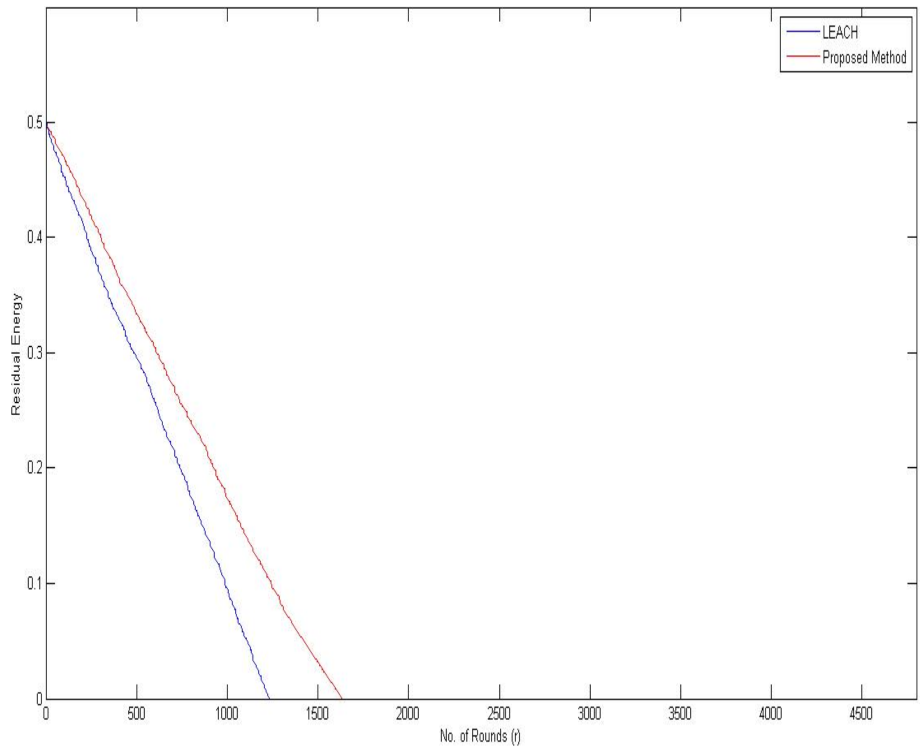

Figure 4.3: Residual energy Plot

Figure 4.3 shows the residual energy plot for LEACH and proposed protocol. As is visible from the graph, the residual energy has shown improvement in the proposed protocol. Thus, the proposed protocol is able to achieve energy efficiency.

CHAPTER 5

CONCLUSION AND FUTURE WORK

The Wireless Sensor networks has been rapidly used in various applications throughout, especially in areas which require continuous monitoring and surveillance. This requires for the sensor nodes to be always active to sense every particular information at every instant of time. This particular requirement however, takes a heavy toll of the power (which is mostly battery powered). Thus, saving energy and battery power so as to prolong the lifetime of the whole network is an important area of research when designing any reliable network setup for such kind of an environment.

In this research work, the energy model of a Wireless Sensor Network was thoroughly studied along with the various protocols which are being used or proposed erstwhile. An important task assigned to the sensor nodes is to relay the information sensed by them to the base station which is a central control center of the entire network. The communication between the sensor nodes and the base station is done through a set of methods which are known as protocols. In this research work a number of clustering protocols were studied and their key features were noted. The LEACH protocol which is a hierarchical protocol where a node becomes a cluster head only if it possesses acertain threshold value is taken as a reference and a modified method which takes into account the distance factor as well has been studied and simulated.

In the network setup, part from the conventional energy threshold criterion being used in most of the LEACH based techniques; this research work also incorporates the distance threshold for deciding the selection of cluster heads in the subsequent rounds. The awareness of the distance of the network helps to understand the network more effectively. Especially, in the case of multi path communication it helps to save the energy wastage. The selection potential i.e. the capability to become the cluster head in a particular round has been evaluated from this distance metric. The energy heterogeneity has been considered with two types of nodes normal and advanced nodes. Proposed method improves the performance of LEACH, as is being shown by different curves like residual energy, number of alive nodes etc. which are a metric for knowing the network lifetime. The method shows that in identical environment as compared to LEACH, which is a standard protocol for comparing the routing methods, the given method improves the performance two-folds.

5.2 Future Work

As mentioned in the above section, the awareness about the network and the position of the nodes can save a lot of energy as well as provide coverage to all the nodes, till the last node is alive. This research work has been constrained to a homogenous network structure with a particular set of network parameters, the work can be extended further to different network environments especially to the heterogeneous environments. Another research paradigm can be to use the concept of selection potential to some other popular clustering protocols. The idea presented in this research can be helpful in guiding future research work in this field.

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