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# Energy Efficient Clustering Algorithm and Data Aggregation in Wireless Sensor Networks

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# CERTIFICATE

This is to certify that the dissertation titled "**Energy Efficient Clustering Algorithm and Data Aggregation in Wireless Sensor Networks**" is a bonafide record of work done at **Delhi Technological University** by **Rahul Kumar, Roll No. 2K12/CSE/12** in partial fulfilment of the requirements for the degree of Master of Technology in Computer Science & Engineering. This work was carried out under my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

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# ABSTRACT

Wireless sensor networks (WSNs) are used in various application such as tracking, monitoring etc. Though WSNs have great potential and are employed in variety of environments, they come with some limitations as the sensor nodes used in WSNs have limited processing capability, low battery power, low bandwidth for communication and less memory space. WSNs contain battery powered nodes where replacement of nodes is impractical. Routing protocols in WSNs aim to maximize the life time of network and energy used by the sensor nodes. Lots of work has been done on how to increase the energy efficiency of the WSNs.

Clustering techniques are used to enhance the life time of network. It reduces the transmission cost and redundancy of data. Sensor nodes send the data to their cluster heads. Cluster heads aggregate the data and send it to the base station. Clustering also enhances the stability period of network which is the time period till all the nodes are alive in the network. Various data aggregation techniques have been proposed to improve the network life time. Thus clustering and data aggregation are important techniques to enhance the network life time. In this dissertation we improve the performance of energy efficient sleep awake and aware protocol on the basis of (1) Cluster head selection (2) Optimal no. of Cluster Heads (CHs) and (3) Multi hop strategy. In this thesis we consider heterogeneous networks to evaluate the performance of proposed energy efficient clustering and data aggregation technique. Our goal is to minimize the energy consumption and extend the life time and stability of network.

Simulation results are shown for the performance analysis of the proposed energy efficient clustering algorithm and data aggregation (EECAA).

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# List of Abbreviations

| | |
|---|---|
| **WSN** | Wireless Sensor Network |
| **BS** | Base Station |
| **SMP** | Sensor Management Protocol |
| **CH** | Cluster Head |
| **SPIN** | Sensor Protocol for Information via Negotiation |
| **HEED** | Hybrid Energy Efficient Distributed Clustering |
| **LEACH** | Low Energy Adaptive Cluster Hierarchy |
| **EEUS** | Energy Efficient Unequal Clustering |
| **PEGASIS** | Power-Efficient Gathering in Sensor Information Systems |
| **GAF** | Geographic Adaptive Fidelity |
| **SEP** | Stable election Protocol |
| **TDMA** | Time Division Multiple Access |
| **TEEN** | Threshold sensitive Energy Efficient sensor Network protocol |
| **APTEEN** | Adaptive Threshold sensitive Energy Efficient sensor Network protocol |
| **GEAR** | Geographical and Energy aware Routing |
| **LEACH-F** | Low Energy Adaptive Cluster Hierarchy with Fix Cluster |
| **ECBDA** | Energy Efficient Cluster based Data Aggregation |
| **PMN** | Primary Master Node |
| **SMN** | Secondary Master Node |
| **ACK** | Acknowledgement |

| | |
|---|---|
| **NF** | Node Factor |
| **DWEHC** | Distributed Energy-Efficient Hierarchical Clustering for Wireless Sensor Networks |
| **DEEC** | Distributed Energy-Efficient Clustering Algorithm |
| **WBCHN** | Weight based Clustering for Heterogeneous Network |
| **EESAA** | Energy efficient Sleep Awake Aware Protocol |
| **MOCA** | Multi Hop Overlapping Clustering |
| **BLAC** | A Novel Battery Level Aware Clustering Scheme Family |
| **PDKC** | Power consumption based on Deployment Knowledge for Cluster based Wireless Sensor Network |
| **CM** | Cluster Member |

# Chapter 1 Introduction

## 1.1 Wireless Sensor Network

A wireless sensor device is a battery operated small device which can perform activities like sensing the physical quantities, storing the data and limited computation and signal processing. Advances in the technology had made it possible to reduce the cost, size, weight of sensors and had considerably increased their efficiency and accuracy. So making use of sensors with the advance networking technology gave rise to a new term called Wireless Sensor Network which can be described as the network consisting of large numbers of wireless capable sensor devices that are capable of sensing, processing and transmitting information by working collaboratively to achieve the common objective. Wireless Sensor Network is used for the monitoring and control applications where sensor nodes gather data and send it to the sink. One of the advantages of wireless sensors networks is their ability to operate unattended in harsh environments in which contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible [1]. The direct transmission of data packets to the sink from nodes in the network causes increased communication costs in terms of energy, average delay and network life time. The routing strategies selection is an important issue for the efficient delivery of the packets to their destination [2]. In wireless sensor network main to increase the life time of network because change of node is impractical. Routing is main challenge in wireless sensor network.

Figure 1.1 defines the sensor node architecture. A sensor node has three modules sensor module to sense the environment, processing module to convert the information from analog to digital signals and wireless communication module to transmit the information to the CHs.

Figure 1.2 clusters are formed to avoid direct communication and cluster heads are responsible to send the data to base station. The nodes in the network are sending the information they have sensed to the CHs. The CHs performs extra computational tasks to reduce the network load and hence increasing the efficiency of the network. After the CHs have processed the data packets they have received they sent the only required useful information to the BS.

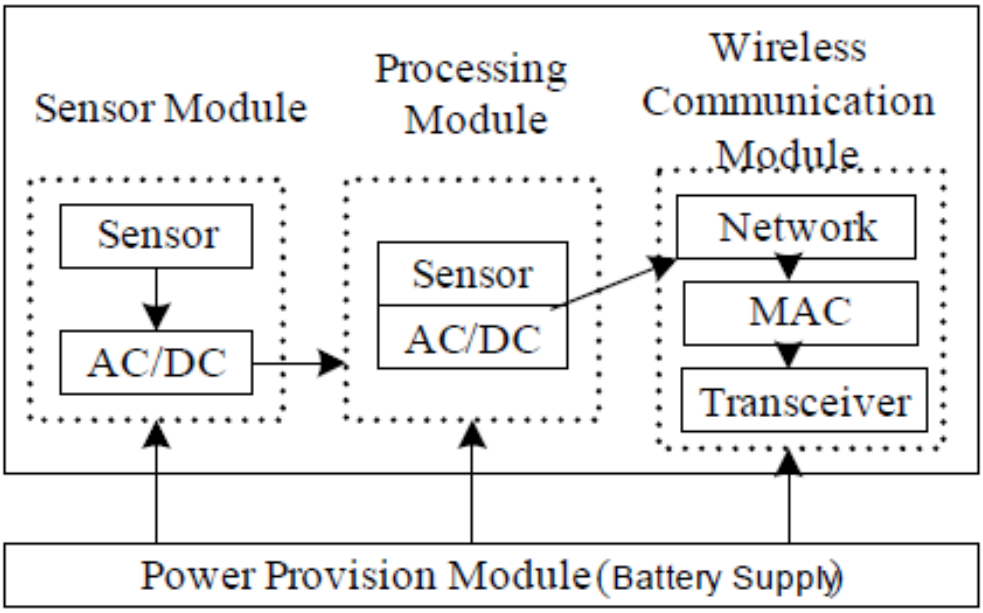


**Figure 1.1 Architecture of WSN Node**

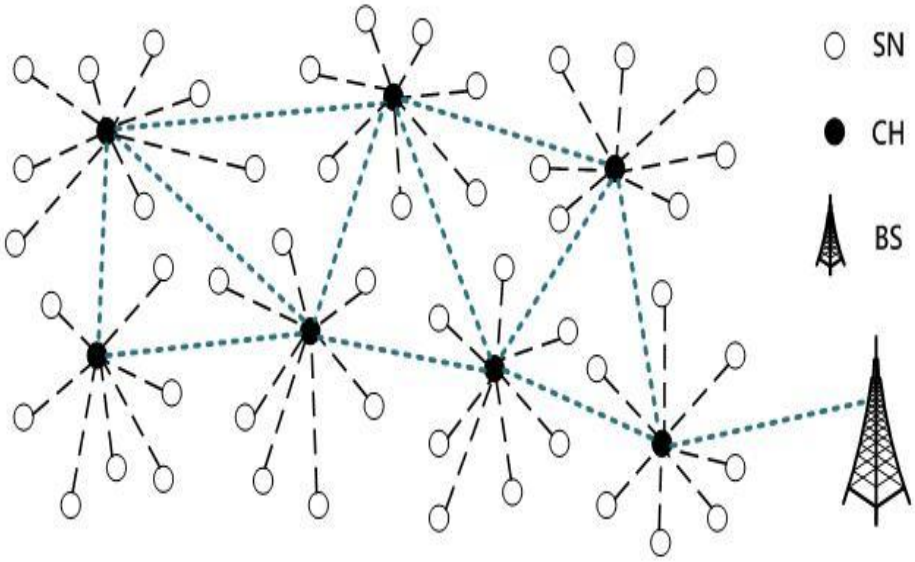


**Figure 1.2 Communication Process in WSNs**

WSNs have various characteristics like power consumption constraints for energy harvesting, ability to manage node failure, heterogeneity of nodes, mobility of nodes, ability to face harsh environment conditions and ease of use. Operating system used by sensor nodes of wireless sensor network is simple and inefficient in comparison to other general purpose operating systems and thus Sensor nodes have the limited processing capability. The BS is the central authority which has unlimited power and has lots of communication and computation capability and it acts as an intermediate communication link between the end user and sensor nodes.

### 1.1.1 Salient Feature of Wireless Sensor Network

The WSN has the following salient features which make it stand in a different class of networks and introduction section described the limitation of network**.**

1. *Large Density of nodes:-*In wireless sensor network nodes range depend on application and area to be covered. Density of node refers to number of nodes in the communication range of single node.
2. *Collaborative objective:* **-**Each node in network senses the activity of area and sends the information to base station. To accomplish this all node work in collaborative nature in spite of competing with each other they inform to base station about the activity of area.
3. *Many to one communication paradigm:-*The main aim of wireless sensor network observes the signal of interest. Data flow two ways in wireless sensor network upstream and downstream. In upstream (many to one) nodes send data to sink .In downstream sink send queries and update to sensor nodes.
4. *Tight limitation in energy, processing power and memory:-*In wireless sensor network nodes are equipped with battery, so there is limited power for processing and storage.

### 1.1.2 Application of Wireless Sensor Network

Wireless sensor network contain various application which can be used as:

1. *Event detection and reporting:*-It contains application intrusion detection as part of forest fire detection system, detecting abnormal behavior, military purpose [3].
2. *Data gathering and periodic reporting:*-It includes application like observing the environmental condition like affecting the harvest, temperature monitoring, monitoring air pollution [4].In these applications require the constant monitoring of area of interest and producing same amount of data which sent to sink.
3. *Tracking based application:* - Applications like border surveillance, movements of suspicious objects, tracking movements and patterns of insects, birds or small animals are included in this class of applications.

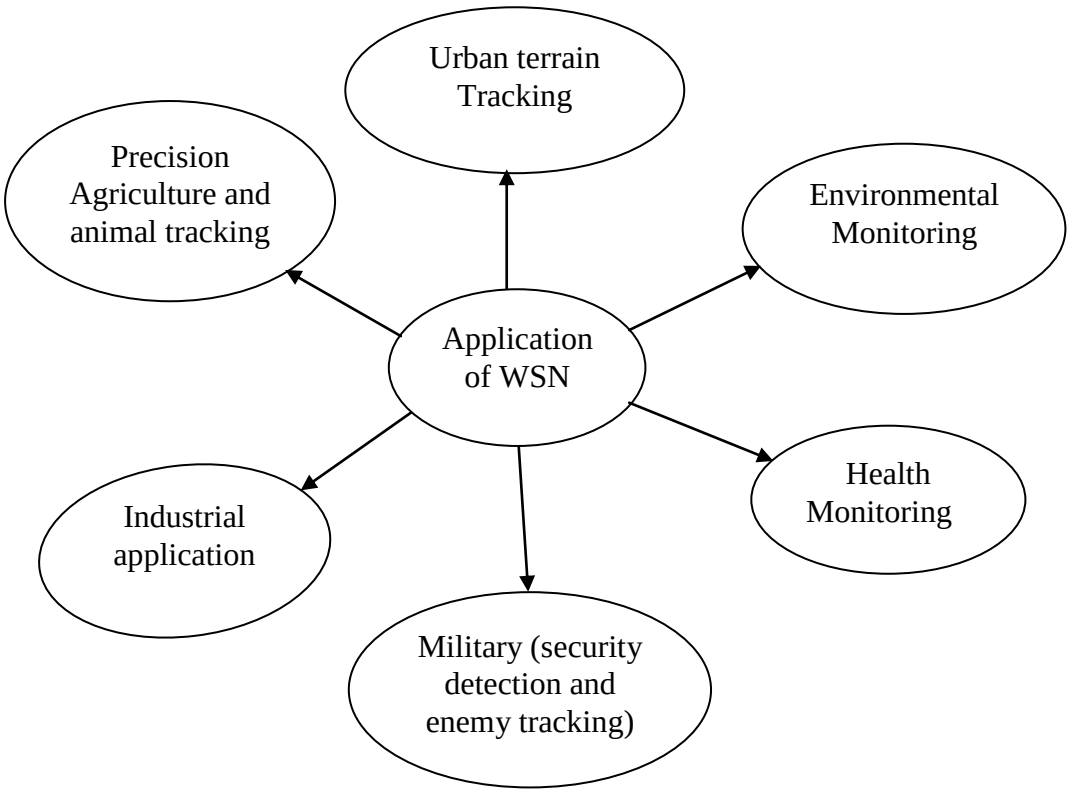


**Figure 1.3 Wireless Sensor Network Applications Overview**

## 1.2 Wireless Sensor Network Protocol Stack

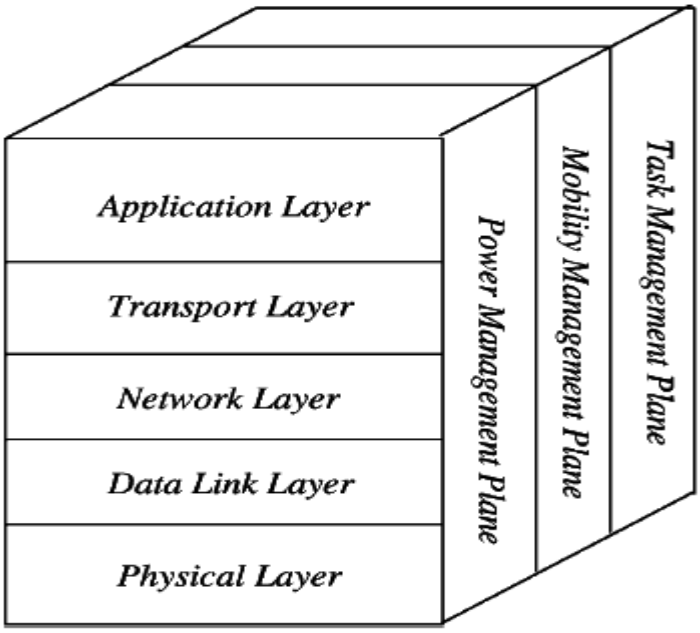


**Figure 1.4 Design of WSN Protocol Stack**

The Sensor network protocol stack is similar to traditional protocol stack, with Application, Transport, Network, Data Link and Physical layer. The wireless sensor network should be aware of the management planes in order to perform operation effectively: Task Management, Mobility Management, and Power Management Planes [5].

(i) Power Management plan manage power consumption and turn off functionality to save energy.

(ii) Mobility Management manages movement of nodes and register, to maintain the route from nodes to sink.

(iii) Task Management responsible for sensing task and data communication should be lower power consumption.

When we are developing the protocol for wireless sensor network, we must address of these management planes.

1. *Physical Layer:* -Physical layer mange's selection of frequency, generation of carrier frequency, modulation and encryption. Its main concern for energy minimization.
2. *Data Link Layer:* -Data link layer manage multiplexing of data flow, detect data frame, error control, medium access control. Specialize medium access control should be associated with sensor network to resolve the energy conservation and data centric routing issue and power saving mode operation.
3. *Network Layer:* -In Designing of network layer must be considered some factor, energy efficiency, location awareness and data centric network. Maintenance of topology or complex route searching should not be more energy consuming.
4. *Transport Layer:* -Transport play role for communication, when system required communicating from outer world. Communication problem between sink and user because data packet does not have information about destination as sensor network is not based on global addressing and attribute name spacing.
5. *Application Layer:* -Sensor Management Protocol used at application layer. SMP help interaction between system programmer and administrator. Sensor Management protocol make transparent use of lower layer software and hardware for sensor network management application. Data Aggregation, Clustering ,Exchange Information for finding location algorithm, Time synchronization, Moving Sensor for enable these communication we have to enable interaction between application between user. SMP provide rules for interaction.

Each layer provides functionality to routing protocol to maintain the communication between the sensor nodes and base station. When we develop a routing technique, we have to maintain the each of the management planes and issues related to all the layers. This provides functionality of communication between nodes, sink and outside world. We must take into consideration lack of global information and infrastructure in WSNs.

## 1.3 Routing in Wireless Sensor Network

Routing is the main issue in wireless sensor network that provide method how the data would be transferred. It is main challenge due to low power wireless sensor network and due to inherent characteristic that make out from other network like cellular and ad hoc network [6].

Various routing technique in wireless sensor network classified as:

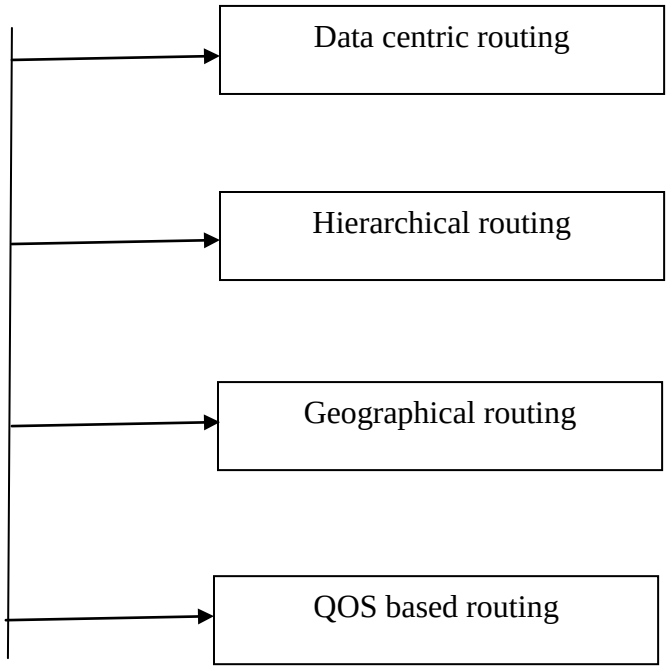


**Figure 1.5 Routing Techniques in Wireless Sensor Network**

In wireless sensor network lack of global identification due to random deployment of sensor nodes so very difficult to communicate with specific set of nodes. So when nodes send data with redundancy. We study various data centric routing protocol such as Directed Diffusion [7], Cougar [8], and Rumor Routing [9],the sensor protocol for information via negotiation (SPIN) [10].In Directed diffusion base station broadcast interest for particular type of data.

Timestamp and several gradient fields associated with interest message. Direction and data rate specify by the gradient.

In SPIN node (initiator) advertise the data to neighbour node if data match the interest type of neighbour then neighbour request for data. Then initiator sends data to sink and negotiation is done using the high level data descriptors which eliminates the data redundancy by using the 3 messages of ACK, REQ and DATA. Every node which receives the data packets broadcasts to all the neighbours that it has received a data message. The ACK contains the meta-data of the data the node has received. Then the neighbours which are interested in data send a REQ message to the node. Then the node sends the DATA message to the nodes which REQ for the data. This is how the transmissions are reduced in and hence SPIN increases the efficiency of the protocol.

Hierarchical routing techniques nodes are grouped known as cluster and each cluster have cluster head, cluster member send data to cluster head, and cluster head aggregate the data and send to sink. Some hierarchical protocols are Leach [11], PEGASIS [12], TEEN [13], APTEEN [14] and HEED [15].In Leach cluster change after each round and cluster head choose on the basis of threshold value. Leach removes the redundancy and long transmission. S. Lindsey et. al[11] proposed improvement of leach in PEGASIS avoid clustering, and node send data to neighbour node and one node send data to sink and aggregation also perform. TEEN reports the sudden change in sensing environment such as temperature.

In geographical based routing sensor node are label by mean of their location. Sensor network required their location with the help of location we can calculate the distance between the two particular nodes and easily estimate the energy consumption. Geographical routing techniques are GAF [16], GEAR [17]. J. Heidemannet.et.al [16] proposed an energy aware routing protocol for energy conservation. In GEAR routing nodes are aware to about location and residual energy and residual energy of neighbour.

QOS aware routing protocol review end to end delay while setting up path in the network. Each node maintains information about neighbour and geographic location to find the path and it gives guarantee end to end delivery. In power constrained WSNs real time application need energy but QOS protocol use low latency and high reliability for deliver the critical data.

### 1.3.1 Routing Challenges and Design Issues in WSN

Wireless sensor network have several restriction such as limited processing power, energy, and limited bandwidth. One of the main design objectives of wireless sensor network is to achieve data communication while trying to extend the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques [6]. Many factor influence designing of routing protocol. We listed some challenge and design issue which affect routing process.

1. *Node Deployment:* - Node deployment is based on application and can be either manual or randomized. In manual deployment, the sensors are placed manually and data is routed along preset paths. The sensor nodes are scattered randomly in random deployment, and create an ad hoc routing infrastructure. Distribution of nodes is not uniform then optimal clustering is required enable to energy-efficient network operation and connectivity.
2. *Energy consumption without losing accuracy:* -In wireless environment, nodes use limited power for transmission and computing. Energy conservation is essential because replacing of nodes is impractical.
3. *Data reporting method:* -Data reporting based on application and time criticality. Data reporting method can be classify as time driven, query driven, event driven and hybrid of all these methods. Time driven data reporting method suitable for application that need periodic data monitoring. In this scenario sensor nodes will periodically switch on their sensor and transmitter. In query driven and event driven react quickly drastic change in sense value due to happen of a certain event or replied to query generated by sink.
4. *Fault tolerance:* -Lack of power results into failure of certain nodes or physical damage. Network should not affected by failure nodes. Medium access control and routing protocol must make the new link for route the data to base station. This may require adjust the power level for transmitting signal and reroute the packet where more energy is available.
5. *Scalability:* -Routing protocol should be able to work with huge number of nodes. They should be enough scalable to respond the base station when any event occur in sensing area.

6. *Network dynamics:* -We study mostly sensor node are fixed and base station too. In various application nodes and base station can be mobile .Decide the route of message from node to base station will be difficult and topology stability is main issue and addition to energy or bandwidth.
7. *Transmission Media:* -In Multi hop sensor network nodes are connected by wireless medium. Fading, high error rate also affect the operation of sensor network.
8. *Connectivity:* -Connectivity based on deployment of nodes. Network size shrinks due to limited energy and node failure. Node should be highly connected because high node density prevents them from cut off to other nodes.
9. *Coverage:* -Sensor contains the limited view of the environment. It contains view of environment in both range and accuracy and cover the limited area of environment.
10. *Data aggregation:* -The main task of data aggregation removes the redundancy from information. When sensors sense the data it can be possible two or more node sensing the same area and sending same information to other node or cluster head. So data aggregation contains various functions which help to remove the redundancy. These techniques improve the efficiency and optimize the information.
11. *Quality of service:* -Some application need data after certain amount of time if data not delivered at particular time, it is useless. Some application does not concern about the energy conservation they require quality of data. If we are not focusing quality of data the information will be useless. In many applications conservation of energy, relate to life time of network.

## 1.4 Motivation

Wireless Sensor Network provides effective solution for wide range of applications. In various wireless sensor network architecture nodes and base station are static. Some mobile node based WSN protocols are proposed recently. Wireless Sensor Network contains limited power so many researchers proposed energy efficient technique to improve the stability and network life time. But there are various issues which are required to be addressed such as redundancy of data and clustering technique. These issues motivate us to research in wireless sensor network and devise a new protocol which should improve stability, network life time and throughput of the network.

## 1.5 Objective

From the motivation we focused on energy efficiency of WSNs. In this thesis we propose a new energy efficient algorithm which improves the stability and life time of the network. Main purpose of this algorithm is to preserve the energy in each round to make the network more stable. Once the sensor nodes are deployed they cannot be replaced or recharged. We use MATLAB to verify the performance of proposed algorithm. We compare the proposed algorithm with existing algorithms on the basis of stability period and alive node after each round.

## 1.6 Thesis Organization

Chapter 1 contains detail introduction of wireless sensor network, routing technique and protocol architecture of sensor network. Literature review, related work, clustering protocol and first order radio model is explained in Chapter 2. In Chapter 3 We describe about the proposed energy efficient algorithm and also the node deployment strategy. Network parameter, Multi-hop communication and Performance results are demonstrated in Chapter 4.We conclude our work with future scope in chapter 5.

# Chapter 2 Literature Survey

The various Energy efficient routing protocol studied have different characteristics in the way they work for the task of achieving energy efficiency .The SPIN protocol which uses push diffusion under Flat networked based data aggregation is suitable for mobile environments where the forwarding decisions are based on local information whereas it does not guarantee data delivery due to changes in the behaviour of the interested nodes. Thus SPIN protocol should not be used in the case when the accuracy and delivery of all the data information is at a high priority [18]. In directed diffusion technique there is no need to maintain a global network topology as in the case of SPIN protocol but it is useful in the case of too many intermediate nodes and less sinks as it uses flooding [7]. Also, directed diffusion is not suitable for WSNs which require continuous delivery of data to the sink. One phase pull diffusion can be an efficient Flat based network data aggregation protocol as it does not uses flooding to know about the interested node but should not be used when the sink interest rate is high. Thus the flat based network data aggregation technique can be used as per the requirements and trade-off to select the most appropriate is discussed. Cluster Based technique is explored along with its variety of routing protocols with the advantages and disadvantages of respective protocols of cluster based techniques. Another approach information similarity based clustering algorithm can be used to save energy as it does not require any global knowledge of the nodes and only cluster heads knowledge is sufficient but increases the burden of the respective cluster head. LEACH protocol used cluster based technique. Various energy efficient routing protocol proposed by researcher to enhance the stability period of network. Lots of work has been done on how to increase the energy efficiency of the wireless sensor networks. Energy efficient clustering technique helps to improve the performance of network because it provides load balancing and manage energy aware communication. In Chapter 1 we discussed some of the routing techniques and challenges in designing of routing techniques.

## 2.1 Clustering in Wireless Sensor Network

In direct transmission each node send data to sink and communication take place directly. But some limitation associated with wireless sensor network such as limited processing capability, low power battery; low bandwidth for communication and less memory space. Replacing of sensor nodes is impossible. Lots of work has been done on how to increase the energy efficiency of the wireless sensor networks. Clustering introduce by W.R. Heinzelman to improve the performance of wireless sensor network. We make the group of nodes and leader of group. Each group member sends data to leader. These groups called by clusters and leader of groups known as cluster head. After selection of cluster head it broadcasts the message to cluster member and on the basis of condition which we set member join the cluster. We will study various algorithm how we select cluster head. Cluster head perform various tasks such as aggregation and communicate to sink. Aggregation removes the redundancy. And various aggregation techniques exist. We are reducing transmission cost with the help of cluster. Data Communication takes place between cluster member and cluster head. Cluster head send data to base station.

Clustering improves the life time of wireless sensor network as compare of direct transmission. Transmissions cost is high as compare to computational cost in wireless sensor network. Various clustering technique proposed in wireless sensor network. Clustering improves the stability of the sensor network. When we deploy the nodes in network they are correlated and sense the same s environment so redundancy occurs in data. So Cluster head use the data aggregation function to remove the redundancy and reduce the cost of transmission as well. Cluster heads choose by various algorithms and there is not useful if cluster head does not perform the data aggregation to remove the redundancy.

Figure 2.1 explains about the several cluster and cluster heads, cluster member sending the data to cluster head and cluster head sending to sink.

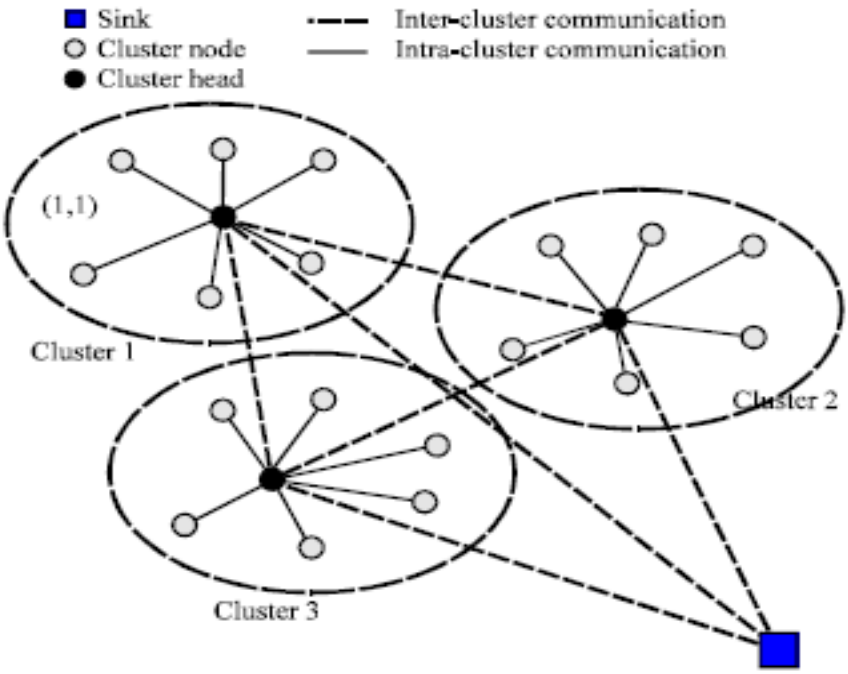


**Figure 2.1 Clustering in Wireless Sensor Network**

## 2.2 Classification of clustering in WSNs

Clustering has various classifications on different criteria. If we are using parameter for electing the cluster head then algorithm can be categorize deterministic and adaptive. Special attribute of sensor node considered in deterministic approach, these attributes are node id and number of neighbour. Lower id node becomes cluster head but this algorithm not suitable for energy constrained network. In adaptive scheme cluster head select on the basis of higher weight. Centralized and Distributed algorithm is part of clustering algorithm. Global information requires in centralized algorithm, Performance of centralized algorithm is not good in large scale network. For large scale network distributed algorithm is appropriate because sensor node use information obtained only its neighbour for joining the cluster or become cluster head. Clustering algorithm can be single hop or multi hop [19].

## 2.3 Challenges for Clustering Algorithm

When we design the clustering algorithm various challenges arise. Some challenge discuss below [19].

1. *Rotating the Role of Cluster Heads:* - In wireless sensor network sensor node transmit the data to particular cluster head. Cluster head perform signal processing and transmit the data to base station. Energy dissipates by cluster head quickly as compare to normal nodes. So change the cluster after each round to achieve the energy efficient communication. Frequently change the cluster head more interruption in network and cluster overhead. If we do not change the cluster head quickly then node will die early.
2. *Optimal Cluster Size:* -Another important parameter is size of cluster. If Cluster size is less then energy consumption is low within each, but cluster heads will be more. Cluster heads dissipate more energy. If we increase the cluster size then each cluster dissipate more radio frequency power. Some clustering protocol contains the equal size of cluster but resulting unequal load on cluster heads. If we use the multi hop communication then which cluster head close to base station which dissipates the more energy. How we can construct optimal size of cluster without location information of nodes this is challenge in sensor network.
3. *Optimum Mode of Communication between Sensor nodes and Cluster Heads:* - Cluster is constructed by sensor nodes and Cluster head receives data from cluster members. Data communication between nodes and cluster head can be single hop or multi hop. In multi hop, the node sends data to nearest node and in single node it directly sends data to cluster head.

When we are designing the clustering protocol for wireless sensor network, consider these issues and challenges occurs .How we can fix these issues and can make the energy efficient algorithm. We have to make the efficient use of energy to increase the network life time and it depends on how we efficiently use the clustering technique. Optimal Clustering depends on the energy model used to achieve better result and how we maintain intra cluster topology. Optimal clustering strategies give better result for energy preserving in each round and make network more stable. These points are describing how we can achieve better algorithm such as maintain transmission cost.

## 2.4 Clustering Objective

Objectives of clustering are to fulfil the essential requirements of the applications. Network Clustering has various popular objectives [20].

1. *Load Balancing:* -This is critical issue in wireless sensor network to achieve the objective. If load is not balance in network some node will die quickly due to purpose of network will be fail. Equal size cluster techniques balance the load and extend the network life time.
2. *Fault Tolerance:* -Sensor network deploy in harsh environment and there risk to physical damage and chance of malfunction. Cluster head require avoiding the loss of information. If cluster head is fail than form the cluster again. Re clustering dissipate the energy.
3. *Increased Connectivity and Reduce Delay:* -Cluster Head communicate with base station and send data to base station. When we select the cluster heads from the sensor nodes, ensure that thee exist a path between the cluster head and base station. Constrained on intra cluster connectivity and concern on data latency.
4. *Maximal Network Longevity:* - Sensors in WSNs have limited power so network life time is major issue. We have to design efficient clustering algorithm which minimize the energy consumption and minimize the intra cluster communication energy. If cluster head place close to sensor node then energy consumption will be low in intra cluster. If we distribute the cluster head load as mention in first point then network life time will be extend.

Application robustness must be the higher priority in WSNs when we design the clustering algorithms and routing protocol and designed algorithm easily adapt the variety of application requirement. If clustering algorithm does not fulfil the requirement of application then it will be useless for particular specification.

## 2.5 Energy Efficient Clustering Algorithms

LEACH was first clustering algorithm. In this algorithm we make cluster and each cluster have sensor nodes, which sense the data and sends data to cluster head [CH].

W. Heinzelman et al proposed LEACH to improve the direct transmission protocol. Before LEACH sensor nodes direct send the data to base station and several nodes can be use as intermediate nodes send data to sink. In each round we choose the cluster heads and they take responsibility for data transmission to base station and every node will be cluster head in one epoch. Epoch is time interval when each node participates for cluster head which node satisfy threshold will be cluster head for particular round. We maintain set G in LEACH G contains those nodes which will be cluster head in further rounds. In first round each nodes have same probability for cluster heads selection, when those selected in first round, they will not be elect as cluster head till next 1/p rounds those nodes that were not selected as cluster head in first round will have higher probability of becoming in subsequent rounds. Each node associated with random number in sensor network for becoming the cluster head (0-1).Sensor nodes eligible for cluster head if they contain random number less than the threshold. Cluster head aggregate the data with the help of function and send to base station. Various improvements made by researcher in LEACH. LEACH-F proposed in this cluster is fixed. Cluster head will change after each round. Wendi Rabiner Heinzelman et al. compared LEACH with minimum transmission energy (MTE) and direct communication.

PEGASIS is enhance version of LEACH protocol, we does not make multiple cluster in this protocol. HEED reduce the complexity of LEACH. It uses degree of node and residual energy or density of node for selection of cluster head. HEED is also known as power balancing protocol. HEED extend the LEACH on the basis of four primary goal first reduce control overhead second goal is selection cluster head is distributive and compact cluster ,third increase network life time on the basis of distributing energy consumption and fourth goal is after constant iteration terminate the clustering process. In LEACH for cluster head selection initial percentage $C_{prob}$ is predefined.

Cluster head selection probability define in HEED define by equation 2.1

$$CH_{prob} = \frac{C_{prob} \cdot E_{residual}}{E_{max}} \quad (2.1)$$

Where $E_{residual}$ is sensor node current estimated residual energy, $E_{max}$ is maximum energy of node at fully charge battery. In HEED cluster can be tentative $CH_{prob}$ <1 or final cluster head if $CH_{prob}$=1 during the round after selection of cluster heads they announcement message about tentative or final cluster head. In HEED cluster head percentage improving with help of residual energy and node selecting as cluster head in successive rounds then it have high residual energy comparison of other nodes.

In chapter 1 we discuss about the TEEN, APTEEN [21] is extended version of TEEN on the basis of performance. LEACH capture the data periodically and TEEN react on time critical event. APTEEN is hybrid protocol which captures the data periodically and reacts on sudden change in sense value. In APTEEN energy efficient communication takes place between sensor and sink because it use hierarchal clustering concept.

Siva Ranjani et. al [22] proposed ECBDA (Energy Efficient cluster based data aggregation) protocol to enhance the stability period of network. In which network is divided into layer and each layer contain the set of cluster. Cluster form by K-means algorithm and cluster head selection on the basis of residual energy. This protocol contain the maintenance phase which help to maintain cluster, when we choose cluster head for particular round if it contain more energy from the threshold this cluster head will be continue for further round until the energy of cluster head less than the threshold value. We does not form cluster also after each round because it use the concept of re clustering. Re-clustering means when the clusters have less than $N_{init}/2$ nodes. When the number of nodes in the clusters is half to that of the neighbour cluster the two clusters are merged and a single cluster is formed. So we are not forming cluster after each round which saving the energy and providing better results.

J. Wu et. al [23] proposed energy efficient unequal clustering technique to improve the network life time and its mechanism based on periodical data gathering in wireless sensor network. In EEUS cluster size is smaller which are close to sink as comparison to far from base station and cluster head closer to sink preserve more energy.

P. Anandhakumar et. al [24] proposed new energy efficient algorithm on the basis of two cluster head selection. There are two cluster head primary and secondary. Main aim of this protocol to saved the energy of sensor nodes and increase the life time of wireless sensor network. Both of them perform different work, first cluster head collects information from its own cluster and known as Primary master nodes. Primary master nodes transmit the data to Secondary master node. Secondary master node aggregates the data and sent to base station. Both of the cluster heads are select on the basis of different criteria. Primary master nodes select on the basis of residual energy and how many time node previously occurred as cluster head. Secondary memory node select on the basis of time factor and data collection performs in efficient manner.

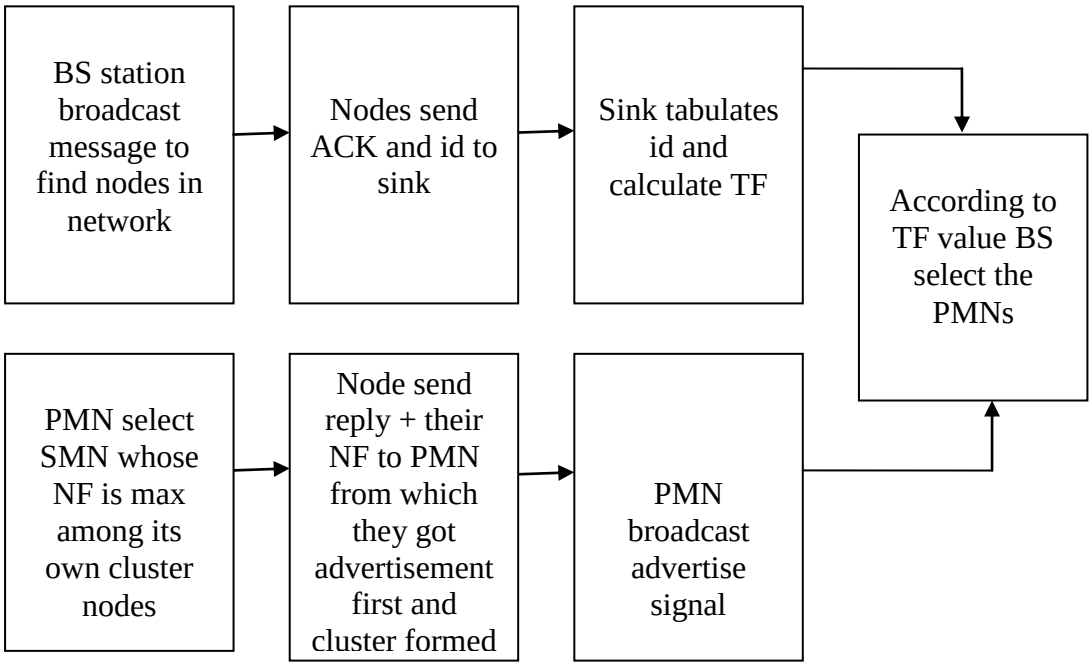


**Figure 2.2 Cluster Formation Process**

Nikhil Marriwala et al [25] proposed an approach to increase the wireless sensor network life time. LEACH provides the selection of cluster head on the basis of random number generation. We cannot ensure that who will be the cluster head in next round. LEACH contains some drawback. Nikhil et al try to overcome the drawback of LEACH. They made improvement in cluster head selection algorithm and optimal path for data transmission. Cluster head selection with the help of residual energy and minimum distance. When cluster head selection process is completed then optimal path from between the cluster heads for data transmission and this approach increases the network life time.

Asha Ahlawat et al [26] proposed the V-LEACH to improve the stability of the network. V-LEACH introduce the concept of the vice cluster head in the cluster. Vice cluster head is alternative option when cluster head will die then it will take the responsibility as cluster head. Vice cluster head select on the basis of maximum energy, minimum distance and minimum energy. It works efficiently to increase the network life time. If cluster head die then whole cluster will be useless and energy also dissipate, to avoid this condition we use this technique and vice cluster take the responsibility as a cluster head.

Ding et al [27] proposed DWEHC to achieve the better result as comparison to HEED. DWEHC main aim is cluster size and intra cluster topology should be optimal. In DWEHC weight function calculates by nodes on the basis of energy preserve and neighbour proximity. Which node has largest weight function will be cluster head and other will be cluster member. Cluster head direct link from sink or base station for communication in first level member. Weight calculates by the each sensor node after neighbour node allocating in this area.

Zhong Liu et al [28] proposed modified LEACH protocol to increase the life time of sensor network. Modified LEACH improves the cluster head selection and size of cluster is restricted. Modified LEACH selects the cluster head on the basis of residual energy and compare advertisement message signal strength with the threshold. Cluster head selection improves by the Chaos PSO. PSO provide the optimum solution for cluster heads selection in WSNs.

Edward J. Coyle et al [29] proposed hierarchal clustering algorithm to achieve the message passing approach use limited energy. Data communication preserves energy in each round to increase the life time of network. In this algorithm cluster form by distributed, randomized algorithm. Hierarchies of cluster heads use this algorithm and increase the level of hierarchy to save the energy. Main aim of this algorithm to minimize the total spent energy for communication. This algorithm provides the optimal parameter to minimize the total energy.

Morteza M. Zanjireh et al [30] proposed A New Clustering Algorithm for Wireless Sensor Network (ANCH).This algorithm focus on the uniformly distribute cluster head over the entire region. Because we want to gets equal size of cluster for each round. Morteza et al focus on the suitable cluster heads to achieve each round optimum cluster. Cluster head selection is crucial for wireless sensor network to achieve better. ANCH reduce the energy consumption to increase the network life time. And these reductions in ANCH improving performance as compare to existing algorithm. Cluster size is essential to increase the performance of network. If clusters are low in network, there will be lots of energy consumption to send the data by cluster member to cluster head .Clusters are high in the network, there cluster head selection consume more energy. And communication range will also be increase because we are increasing cluster head so transmission will increase also. If cluster size is not uniform there is lots of energy is wasting. ANCH aims to form optimum size of cluster to preserve the energy and select the suitable cluster head.

Expected Number of Cluster Members clustering technique proposed to prolong the life time of network. Cluster head communicate directly with the base station. This algorithm proposes technique to make the group of cluster member with the help of different cluster heads and Huiying Wei et al [31] calculate the average value. Main aim of this algorithm each cluster head dissipate energy to get the average value. Each node calculates the approximate distance from sink with the help of sink broadcast message for all node. This algorithm balances the load and average consumption of energy. When each cluster head dissipate the average energy for communication thus network stable period increase and network life of sensor network.

Clustering Protocol has two broad categories Homogenous and Heterogeneous. LEACH, TEEN, ANCH are homogenous and SEP, DEEC are heterogeneous protocol. Heterogeneity in sensor node energy because of we introduce some higher energy node, Transmission levels can be different for sensor nodes and initial energy can be different [32].In Heterogeneous network some node can be introduce with higher energy known as advance nodes. Selection of cluster heads on the basis of residual energy, advance node will be cluster head which help to improve the life time of the network. Cluster head contain more energy as comparison of the cluster member.

Various clustering algorithm proposed for heterogeneous network also. Heterogeneity helps to improve the stability period of sensor network. Advance node concept arrives from stable election protocol in this algorithm advance nodes have higher energy as comparison of other nodes. Advance nodes select as cluster heads which help to improve the performance of network. Cluster heads selection in LEACH on this basis of random number generation and Cluster heads do various task such as aggregations and send data to base station. We will discuss various clustering technique which are based on the heterogeneity of wireless sensor network and selection of cluster head on the basis of same transmission radius which node is advance node. We can say select high energy node as cluster head with in transmission radius.

Georgios Smaragdakis et al proposed Stable election protocol for heterogeneous sensor network. Sensor nodes are not mobile and it improves the time of first node death which known as the stability period of network. Stable election protocol depend each node weighted selection probabilities to become cluster head each node remaining energy. Stable region improve by the Stable election protocol .Heterogeneity parameter use by the clustering hierarchy such as advance nodes which contain more energy as compare to normal nodes and additional energy. Balance energy consumption try to maintain by Stable election protocol. Advance node should be cluster head as comparison of normal nodes which contain the initial energy. Existing LEACH improvement make by increase the epoch proportion to energy. We increase the epoch on the basis of energy increase of nodes. Stability period of Stable election protocol is higher due to this throughput of stable election protocol is greater as compare to other protocol. LEACH very sensitive about the heterogeneity and it is not stable when network is heterogeneous.

In Stable election protocol we do not require about the energy global knowledge after each selection round and provides the optimal clustering technique and this works on

the probabilistic algorithm. Stable election protocol uses the two levels of hierarchy nodes. There are two types of nodes advance and normal and we have to indicate also how much fraction more energy contains by the advance nodes and with the help of fraction we improve the epoch. Stable election protocol tries to maintain the balance of power to achieve the stability. Stable election protocol contain problem to maintain well distributed energy consumption constrained in the stable period. There can be worse if all normal nodes select as cluster heads so we have to maintain the well distributed energy consumption constrained. Threshold increases with number of round and each epoch. Stable election protocol improves stability as comparison of other energy efficient protocol and it also improves network life time and throughput.

Ravi Tondon et. al [33] proposed weight based clustering in wireless sensor network to improve the performance of network. Cluster head dissipate more energy as comparison of other nodes. Advance nodes select as cluster head improve the performance. In this algorithm cluster head selection on the basis of weight based clustering for heterogeneous network. WBCHN consider on various point residual energy, how many sensor node live neighbour and with the help of forecast method. If residual energy of sensor node is greater than the average energy of all neighbourhoods, node will elect itself as cluster head. There is exception in rule after selection of cluster head as node, node energy become equal to minimum energy the node will be consider as dead, because it lie below the threshold. So after each round pass the "I am alive "message to neighbour with the help of this information node can be predict how many neighbour are alive and predict the energy for current round and weight broadcast by nodes(remaining energy after current round) and higher residual energy node will be select as cluster head. Weight calculated as:

$$(Energy_{reidual})_i = (E_{current})_i - (Energy_{require})_i \quad (2.2)$$

In WBCHN weight function calculated with help of equation 2. WBCHN attempts to maintain load balancing. Maximum energy node selected as cluster head because cluster have to perform various task such as transmission and data aggregation.

Energy efficient Sleep awake aware protocol (EESAA) considers node schedule "sleep" and "active" mode during a single interval communication. EESAA provided the pairing concept of nodes. Main Purpose of this protocol to avoid the redundant data .When nodes are coupled, they sense the same data and send to Cluster Head. EESAA provide the pairing (coupled nodes) concept to increase the life time of network on the basis of when two nodes coupled, at a time one node will be in active mode. EESAA able to minimize energy consumption because nodes in Sleep-modes save their energy by not communicating with the CHs [34].This protocol based on homogenous network. Main aim of this protocol to minimizes the redundancy in data. Cluster head choose in first with help of LEACH. And afterwards energy of nodes will be different then choose cluster heads on the basis of energy. Deployment of nodes in network is random.

Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks proposed by Li Qing et al [35] to enhances the scalability and network life time. And provide key technique to reduce the energy consumption. It is called as DEEC. Cluster heads selection with the help of probability based on the ratio residual energy of each node and network average energy. And which nodes have high residual energy and initial energy they have more chance to become cluster head. It reduces the energy consumption with the help average energy of the network. In every selection round global knowledge is not required by DEEC. It is multilevel heterogeneous protocol. DEEC provide the more scalability and more life time as comparison of stable election protocol (SEP) and LEACH. Its increases 15 % round then the stable election protocol for stability period.

| | **SPIN** | **LEACH** | **Directed Diffusion** |
|---|---|---|---|
| Optimal Route | NO | NO | YES |
| Network Lifetime | Good | Very Good | Good |
| Resource Awareness | YES | YES | YES |
| Use Of Metadata | YES | NO | YES |

**Table 2.1 Comparison between Routing Protocols**

Table 2.1 describing the characteristics of the routing protocol there are data centric routing and clustering technique and we can measure table clustering protocol providing the more lifetime and also providing the optimal route. In some case data centric routing protocol can be better as compare to clustering protocols.

We studied various clustering protocol some provides the various technique how we can stable our network more and how we can improve the life time of network. Heterogeneity provide more stable network as compare of homogenous network.

Clustering technique reduce the redundancy in data and clustering algorithm contains the various type of technique such as hierarchical, distributed, centralize. We focus on the cluster properties which contain the cluster count, intra cluster topology, inter cluster topology and stability and cluster count. Extended HEED [36] contains variable cluster count and fixed intra cluster topology single hop and inter cluster topology contain the direct link between the cluster head and base station. Stability assumed in extended HEED. Cluster head capabilities define in extended HEED. Cluster head is stationary and aggregate the data. It is distributed methodology and selection of cluster head randomly and it saves energy.

Huang and Wu extended HEED on the basis node will not give up which did not hear from any cluster head (Orphaned nodes).In extended HEED we consider these nodes as cluster head and communicate directly to base station does not require re execute the algorithm. These modifications decrease the cluster head count.

Various clustering algorithm make great effort to construct minimum number of disjoint cluster. Youssef et al. [37] proposed that overlapping of cluster facilitate various applications such as inter cluster topology, localization of nodes and cluster head failure recovery. Youssef proposed MOCA (Multi hop Overlapping Clustering Algorithm).In MOCA each node has p probability to become a cluster head. Each cluster head broadcast message with in its radio range. This message forward k-hop away sensor nodes only. Cluster head receive request to join cluster by all sensor nodes which hear broadcast message. Node contains the ID of all cluster heads it heard from. Overlapping degree and number of cluster control by the probability p. MOCA proposed for overlapping degree and number of cluster. If number of cluster is appropriate then number of cluster head also is suitable for communication with base station. This maintains the overlapping degree and author selects the suitable the value of p to maintain the overlapping degree and particular cluster count.

Vaibhav V. Deshpande et al [38] proposed algorithm to make the cluster of cluster head in wireless sensor network. Intra cluster and intra cluster communication mange by cluster head. Make the cluster of cluster head is suitable way to improve the network life time. If cluster head fail we have to maintain the cluster again. Lots of energy consume by these activities. To avoid this extra energy consumption make cluster of cluster heads. In this cluster we choose the leader of cluster and leadership rotating among the cluster heads after number of preset round communication.

Tony Ducrocq et al [39] proposed new algorithm to optimize the network life time. Clustering provide efficient way to organize the network. Cluster head perform various tasks such as gathering of data, aggregation of data and send data to base station. So they exhaust quickly. Cluster head selection in this algorithm on the basis of BLAC (a novel battery level aware clustering scheme family).For balance energy consumption cluster head responsibility taken by alternatively by each node. This balances the energy consumption to increase the network life time. Cluster head role rotating and each node taking the responsibility.

Wireless sensor network contains the huge number of sensor nodes with limited power. Clustering algorithm provide way to reduce energy consumption. Maryam Soleimani et al [40] propose new algorithm PDKC and it is based on knowledge of node deployment. This use the Gaussian probability distribution function to modelled the node location in place of GPS and other device. This algorithm enhance the network life time. In this algorithm we use the deployment information of nodes, nodes residual energy, degree of nodes and distance from base station for selection of cluster head and improve the network life time. This clustering algorithm improves the coverage region of network. PDKC (Power consumption based on Deployment Knowledge for Cluster based Wireless Sensor Network) improves the energy consumption.

Clustering algorithms helps to remove the redundancy in information, because cluster head perform the data aggregation. We have discuss various clustering algorithm such as distributive, centralize and hierarchal algorithm. Each clustering algorithm focus on clustering objectives to improves the network life time and how we can minimize the energy consumption.

## 2.6 First Order Radio Model

Data aggregation and transmission are the most important component for node energy consumption. First radio energy model describe how much energy will be dissipate for transmission and receive the message. Energy consumption by transmitter to rum the radio electronics and power amplifier and receiver dissipate the energy to run the radio electronics [32]. In this model we consider both path free space and multi path. This model shifts the energy dissipation according to condition. Various assumptions use for energy dissipation for transmit and receive the message and it change the advantage of protocols [12]

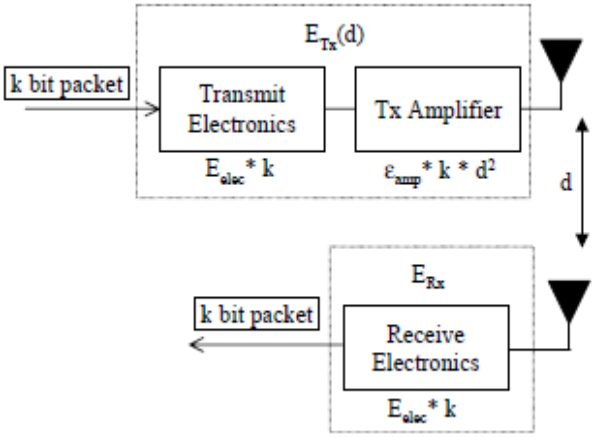


**Figure 2.3 First Order Radio Model**

In this model k bit of message we are transmitting and receiving. Transmission energy for packet $E_{Tx}$ and receiving energy $E_{Rx.}$ We want to make our protocol better then should try to minimize energy consumption. We make very assumption about the radio energy model to make the better protocol. Various clustering objective depend on energy model used.

In Order to get a suitable signal to noise ratio (SNR) in transmitting k-bit message over a distance d, energy consumed by radio for transmission.

$$E_{Tx}(k,d) = \begin{cases} k \times Eelec + k \times \varepsilon_{fs}.d^2 & if\ d < d_0 \\ k \times Eelec + k \times \varepsilon_{mp}.d^4 & if\ d \geq d_0 \end{cases} \quad (2.3)$$

Where: *Eelec* used to run transmitter circuit or receiver circuit for per bit energy dissipation. Parameter $\varepsilon_{fs}$ and $\varepsilon_{mp}$ depend on transmitter amplifier model and dissipate the energy per bit on the basis of distance and distance between sender and receiver is d and k bit of packet. We get $d_0$:

$$d_o = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \tag{2.4}$$

For receiving the *k*-bit message radio

$$E_{Tx} = k \times Eelec \tag{2.5}$$

In above equation 2.3 use both $d^2$ for free space and for multi path use $d^4$ to achieve the minimum energy consumption for transmission over distance d.

Energy model expend for k-bit data aggregating

$$E_{da-fus} = k \times E_{da} \tag{2.6}$$

Where $E_{da}$ is energy dissipation for aggregating the data .Data aggregation removes the redundancy from the data and it helps to improve the network stability.

# Chapter 3 Proposed Approach

In this chapter, we propose an energy efficient clustering and data aggregation technique for heterogeneous networks. Our goal is to minimize the energy consumption and extend the life time and stability of network. We use the node pairing technique to improve the network life time and we also propose a novel cluster head selection technique. We choose the cluster heads for efficient communication in the network. How many clusters can full fill the requirement of transmission? To reduce the overhead we try to maintain optimal count of cluster heads or optimal clusters for transmission. Cluster head aggregates the data and then send data to sink or base station. We do not know about how far clusters are formed from the base station, CHs sends the data to the BS directly in single hop communication. In our algorithm we maintain an optimal path from cluster heads to base station. Reducing the redundancy , reducing overhead of clustering technique, electing best cluster head on the basis of residual energy and reducing the transmission cost in our algorithm increases the efficiency of the network. In our algorithm we use first order radio model for transmission, to receive the data from one node to another. Cluster head performs data aggregation which dissipates some energy but helps to reduce the cost of data transmission. We assume transmission cost is more as compared to computational cost. Clustering technique dissipates more energy to form clusters and for the selection of cluster head. In our algorithm we choose higher energy nodes as cluster heads as the cluster head with more energy can efficiently perform the extra computation tasks. The proposed algorithm avoids re-clustering and save energy of the network. As cluster head performs various tasks and if cluster head dies then we have to construct the cluster again which consumes more energy. So this technique avoids the re-clustering.

In proposed model we will describe the network deployment strategy, optimal cluster, cluster head selection technique, optimal no. of cluster heads, and optimal path technique. Proposed algorithm is observed to be more efficient than existing routing protocols like SEP, LEACH, and EESAA in terms of stability period and network lifetime. In intra cluster we use single hop transmission and inter cluster communication takes place with the help of multi hop strategy.

## 3.1 Network Deployment Model

We consider there are *N* sensors Node which are uniformly dispersed within $M \times M$ square area. We used three level heterogeneous models means there are three types of sensor nodes super nodes, advance and normal nodes. Assume $E_0$ is the initial energy for normal nodes. Super nodes contain '*a*' times more energy from the normal nodes and *S* fraction of super nodes and *M* fraction of advance nodes. Thus *sN* super node contain $E_0\ (1+a)$ energy, mN advance nodes contain $E_0\ (1+b)$ energy and (*1-S-M)* normal nodes contain $E_0$ energy. So our network model contains three types of nodes super advance and normal. Network contains uniformly random deployment of sensor nodes. Total energy of nodes will equal to

$$E_{total} = N(1-S-M)E_0 + NSE_0(1+a) + NME_0(1+b) \quad (3.1)$$

Where *S* fraction nodes is super
*M* fraction nodes is advance
$E_0$ is initial energy of network

Total energy of network in simplified form

$$E_{total} = NE_o + NSaE_0 + NMbE_0 \quad (3.2)$$

Where '*a*' and '*b*' are how much energy increased of sensor nodes. These values defined in network parameter.

Heterogeneous model define that each nodes have different energy level and different sensing range but in proposed algorithm considered different power of sensor node. This is our heterogeneous model which we use for communication and using these fractions of nodes to reduce the energy consumption. These are the assumptions we use in our proposed algorithm and network deployment model of our proposed algorithm have three type of node and which have different energy level. Equation 3.2 defines the total energy of sensor nodes and nodes are deployed uniformly in sensor network region. These sensor nodes sense the environment activity and send to their cluster head which transmit the data to base station.

## 3.2 Node State

When we are deploying nodes in the sensor network, some node deployed close to each other so they will sense the same data. Cluster head getting the same data both of the nodes which are useless and consuming the energy also. In our algorithm whose nodes making a pair with other nodes at a time one node will be in active state and other will be in sleep state. Base station decides which nodes are coupled or paired. Sensor nodes measure their location through GPS [34]. Nodes transmit their location to base station. Base station utilizes this information and compute distance between nodes. Nodes decide their state on the basis of coupling information and neighbour state. Then base station broadcast the coupled nodes information to all nodes in the network. When we deploy the nodes in field some node deployed near to each other. Which are coupled on the basis of distance between the nodes they will sense the same data and send to cluster head means same information sending by two other nodes so we introduce the concept of coupled nodes. The nodes switch between "active" and "sleep" state during single communication interval. During coupling process some nodes left out because they are not coupled to any other node. Which nodes are not coupled they will always in active state and join the suitable cluster. With the help of this technique we can reduce transmission cost within the cluster and avoid extra data which is useless for user.

We decide the pairing of nodes on the basis of distance between them, which helps to improve the performance of protocol. We are saving energy of the nodes in each round, due to stability period of network increases and hence the lifetime of every node also increases. We decide on the basis of algorithm about the paired nodes whether they will be in active state or sleep state for particular transmission.

```
Start of Round

if ( node == paired ) then

                    if ( node .state==active && CCH FLAG==1) then

                        node.state=active

                    else if (node.state==active&&CCH FLAG==0) then

                        node.state = sleep

                    else if (node.state==sleep&&neighbour CCH FLAG==1) then

                        node.state=sleep

                    else if (node. state==sleep&&neighbour CCH FLAG==0) then

                        node.state = active

                    end if

  else if (node==paired && node neighbour==dead) then

            node.state=active

     else

          node.state = active

    end if

End of Round
```

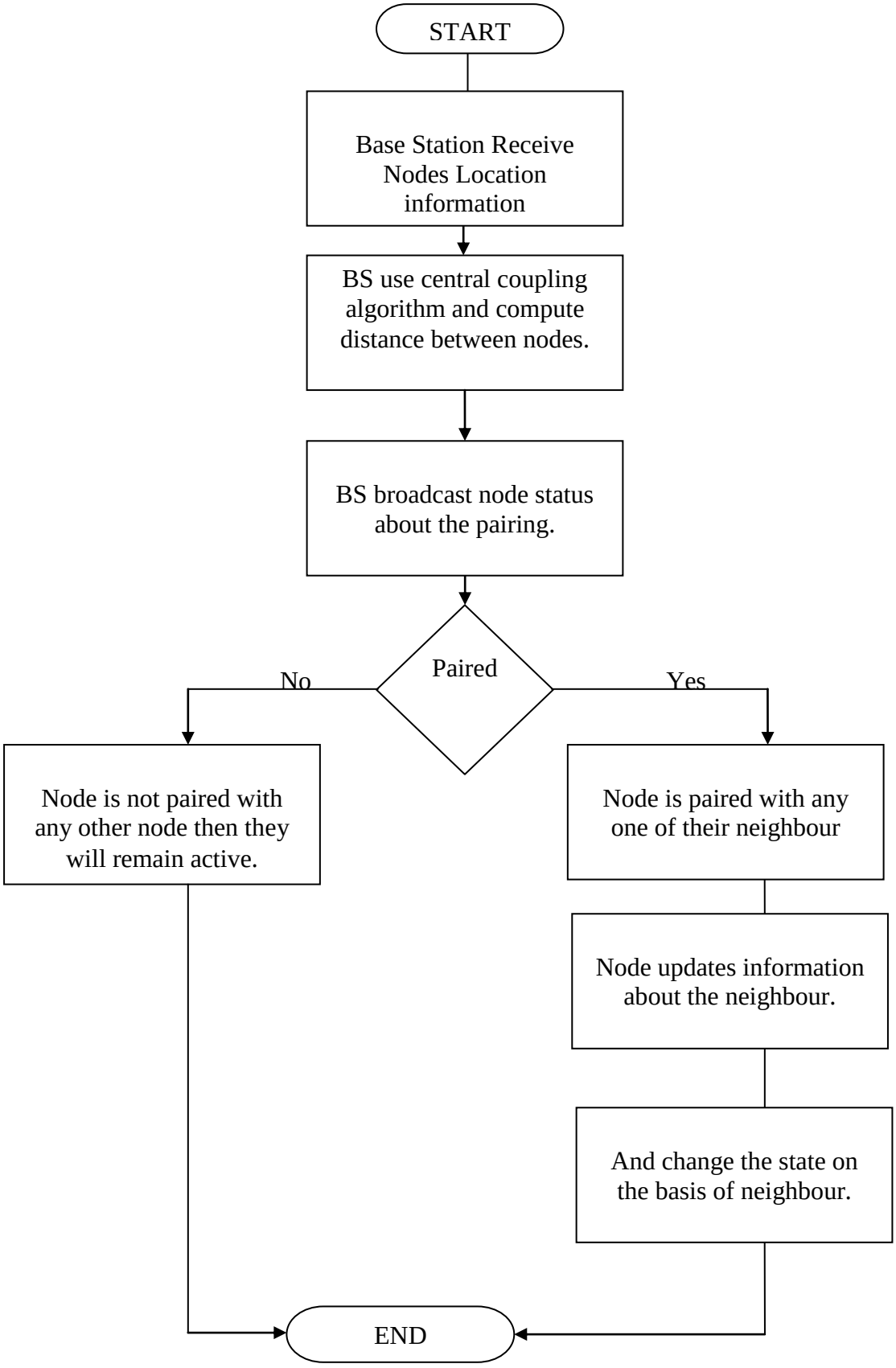


**Figure 3.1 Flow chart for Paired Node**

## 3.3 Optimal Number of Cluster

Clustering in wireless sensor network contain various challenge if we want to improve the efficiency of algorithm. We have to optimize the clustering technique and try to reduce the energy consumption by clustering. In clustering technique we form the cluster and cluster member send data to base station. On the basis of probability we find out the $C_{opt}$ to construct the optimal cluster. It is not possible always form the optimal clustering during each round. If number of cluster is more than more cluster heads will be construct and they will communicate to base so more energy consumption occurs. And forming the cluster and selection of cluster head also consume the energy. Optimal cluster technique reduces energy consumption and it will improve the total throughput of algorithm.

We are assuming $M \times M$ square area of network and $N$ sensor node deployed in this area. Assuming Base station is not at centre. Cluster head node consuming energy during each round and assuming base station distance from cluster head less than $d_0$.

$$E_{CH} = \left(\frac{N}{C} - 1\right) \times k \times Eelec + \frac{N}{C} \times k \times E_{DA} + k \times \varepsilon_{fs} d^2_{to\ BS} \quad (3.1)$$

Where $C$ is number of cluster, $E_{DA}$ data aggregation cost, average distance between base station and cluster head denoted by $d_{to\ BS}$ and $k$ is number of bit of packet or message.

Node cluster head node energy consume calculated by

$$E_{CM} = k \times Eelec + k \times \varepsilon_{fs} d^2_{to\ CH} \quad (3.2)$$

Where Energy consumed by the cluster member is $E_{CM}$ and distance between cluster member and cluster head is $d_{to\ CH.}$

Each Cluster consumed E $_{cluster}$ energy in each round

$$E_{cluster} \approx E_{CH} + \frac{N}{C} E_{CM} \quad (3.3)$$

Energy dissipated in network is calculated as

$$E_{Total} = C(2N \times Eelec + N \times E_{DA} + \varepsilon_{fs}(k \times d^2_{to\ BS} + N \times d^2_{to\ CH}) \quad (3.4)$$

According to equation

$$d^2_{to\ CH} = \int_{x=0}^{x=x_{max}} \int_{y=0}^{y=y_{max}} (x^2 + y^2)\rho(x, y)\, dx\, dy = \frac{M^2}{2\pi C} \quad (3.5)$$

And

$$d^2_{to\ BS} = \oint_A \sqrt{x^2 + y^2}\, \frac{1}{A}.dA = \frac{0.765M}{2} \quad (3.6)$$

We are differentiating total energy with respect to total number of cluster to find out the optimal number of cluster.

$$C_{opt} = \sqrt{\frac{N}{2\pi}}.\frac{M}{d^2_{to\ BS}}.\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (3.7)$$

$C_{opt}$ value provides the optimal number of cluster which should form in network to reduce the communication energy consumption and reducing clustering energy.

## 3.4 Cluster Head Selection

Cluster head selection technique play vital role to improve the network life time and make the network more stable. Cluster head perform various tasks such as broadcast the message to all nodes and nodes on the basis of distance join the cluster head. Cluster member send information to cluster head. Cluster head receive data from all cluster member in section 2.6 we study about the energy model that determine node dissipate the energy during receive the data from other node. Cluster head also perform the data aggregation which removes the redundancy from the information and reduce the transmission cost.

We are selecting the cluster head on the basis of residual energy of nodes and higher energy nodes probability will be higher for electing as a cluster head.

Let us assume that S is fraction of total nodes that are s-nodes and M is the fraction of total nodes that are m-nodes. The energy of s-node is 'a' times higher than normal node, while the energy of m node is b time higher than normal nodes. If initial energy of a normal-node is $E_0$ then total energy of all the nodes will be and w normal nodes:

$$E_{total} = N(1 - S - M)E_0 + NSE_0(1 + a) + NME_0(1 + b)$$

Optimal probability of cluster head selection in case of homogeneous network is given by [5]:

$$P_{opt} = \frac{C_{opt}}{N} \tag{3.7}$$

Where $C_{opt}$ is optimal number of cluster heads and N is total number of nodes in network and we used the $P_{opt}$ in proposed algorithm to find out the probability for each fraction of nodes. In cluster heads selection we used the residual energy of each node because high energy nodes have higher probability to become cluster heads. In equation 3.8, 3.9 and3.10 we define the probability for each types of node.

Now optimal probability of a node to be cluster head on the basis of residual energy can be calculated as:

$$(P_w)_i = \frac{P_{opt}\ E_i(r)}{(1+Ss+Mm)\bar{E}(r)} \tag{3.8}$$

$$(P_m)_i = \frac{(1+b)P_{opt}\ E_i(r)}{(1+Ss+Mm)\bar{E}(r)} \tag{3.9}$$

$$(P_s)_i = \frac{(1+a)P_{opt}\ E_i(r)}{(1+Ss+Mm)\bar{E}(r)} \tag{3.10}$$

Where $E_i\ (r)$ is the residual energy of $i^{th}$ node in $r^{th}$ round and $\bar{E}(r)$ is the average energy in the $r^{th}$ round. These are the probability for three types of nodes to become the cluster head and advance node contains the highest probability to become cluster hand in further rounds. But we have to set corresponding threshold value for each type of nodes.

Depending on the weighted probabilities the threshold values can be calculated as follows:

*(1) For w normal nodes threshold value will be equal to*

$$T_w = \begin{cases} \frac{p_w}{1-p_w\left[r \bmod \frac{1}{p_w}\right]} & if\ \ w \in G \\ o & otherwise \end{cases} \tag{3.11}$$

*(2) For m advance node threshold value will be equal to*

$$T_m = \begin{cases} \frac{p_m}{1-p_m\left[r \bmod \frac{1}{p_m}\right]} & if\ \ w \in G' \\ o & otherwise \end{cases} \tag{3.12}$$

*(3) For s super node threshold value will be equal to*

$$T_s = \begin{cases} \frac{p_s}{1-p_s\left[r \bmod \frac{1}{p_s}\right]} & if\ w \in G'' \\ o & otherwise \end{cases} \quad (3.13)$$

Where *G, G'* and *G''* are the sets of *s*, *m*, *w*-nodes that have not been the cluster head in last epoch respectively. Random number generate by node which lie between [0, 1]. Random number comparison with threshold value if value of random number is less than the particular threshold value node will elect as cluster head for current round.

After the selection of cluster head, it broadcast the message to all nodes. Node receives the signal and decides on the basis of distance from particular cluster head. If we will select the cluster head on the basis of distance then intra cluster cost of communication will be less.

In this algorithm we use the multi hop strategy to transmit the data from cluster head to base station. In this algorithm higher energy node are cluster heads and we maintain clustering objectives to improve the performance of the algorithm. We consider the network to be heterogeneous for our proposed energy efficient algorithm.

## 3.5 Optimization of Cluster Head Count

If clustering algorithm contains various cluster heads then transmission cost will be high. But we want to reduce the energy consumption in transmission to enhance the network life time.

Probabilistic algorithm gives the $k_{opt}$ value for the optimal cluster head but we cannot ensure that value of cluster heads is optimal. So our purpose to maintain the optimal cluster head in the network. W.B. Heinzelman et al. [12] prove that there will be 3 to 5 cluster from 100 nodes in the network. We assume 5% near optimal percentage. For maintain the constant cluster head number $N \times p$. N is total number of node and $p$ is percentage for cluster head. We get residual energy of nodes learned by cluster head advertisement message. If number of cluster head is less than $N \times p$ then we will select the nodes from cluster head and set timer for every node [41]. The shortest time interval node broadcast Cluster head advertisement message.

Time interval

$$T = l/E \tag{3.12}$$

Where $l$ is factor and $E$ is residual energy. The node with high residual energy will have lesser time interval.

If cluster head is more than $N \times p$ then it will be sorted on the residual energy basis and those with lower energy will be eliminated to change the number of cluster head. Optimization of Cluster Head Count reducing extra transmission cost. In this algorithm we are selecting cluster head on the basis of the residual energy of nodes. In number of less cluster head node will exhaust early due to transmission range will be high and one issue can also some cluster head exhaust rapidly. We are increasing load on cluster head, so load should be uniformly distributed which help to improve stability of network. We are using this concept in our model to improve the performance. In this algorithm we are handling only when cluster head is more than $N \times p$.

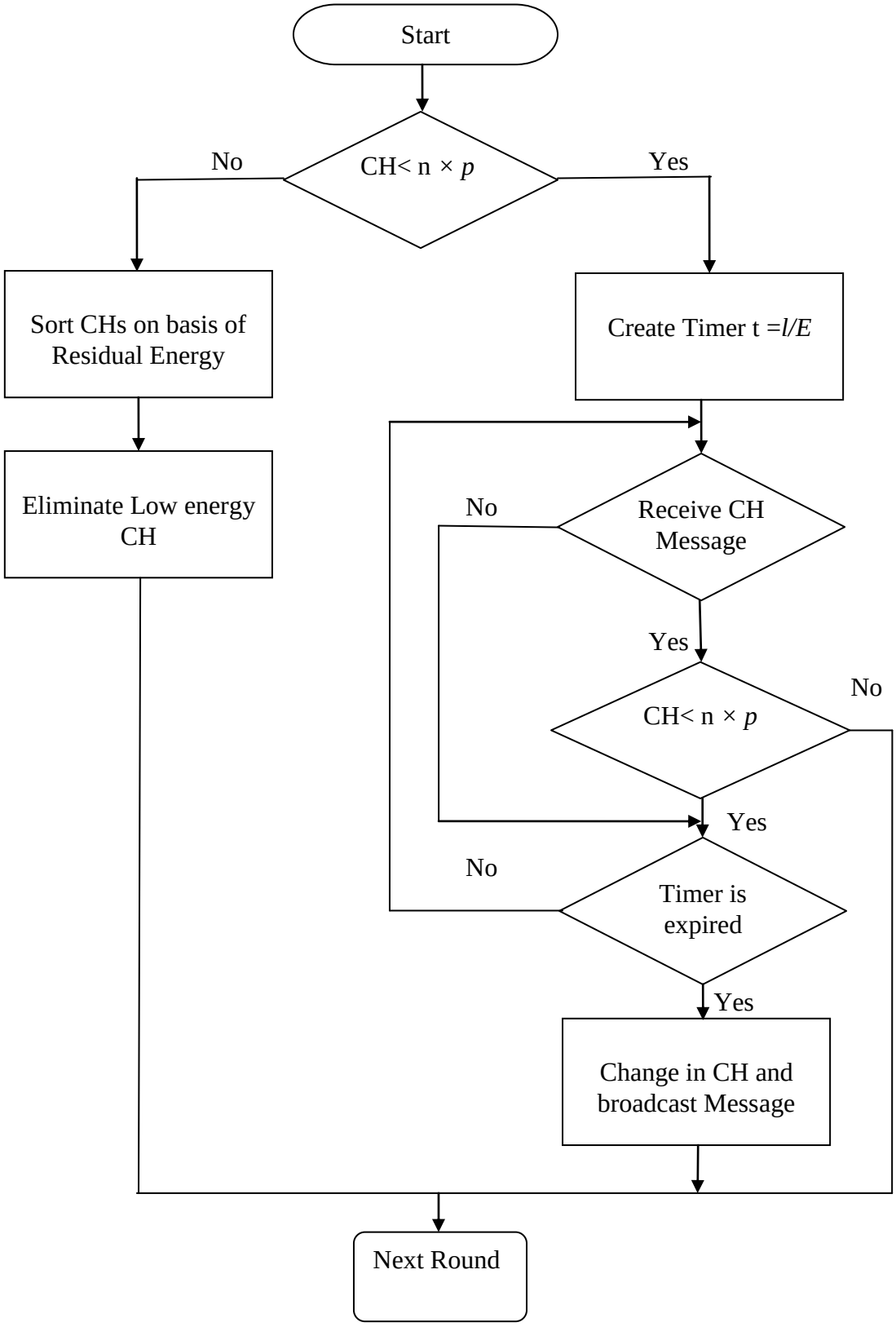


**Figure 3.2 Flow Chart for Optimization of Cluster Heads Count**

## 3.6 Multi hop Communication

When we transmit the data directly to base station from the first level cluster head energy consumption is more in such transmissions. So we use multi hop communication concept to find the optimal path to the BS in the network. Cluster heads receive data from cluster members and aggregate the received data and then send it to the nearest cluster head and not directly to base station.

We have increased the number of levels where cluster heads are performing data aggregation in the proposed algorithm. In every round, there will be change in cluster head nodes as cluster head selection is done dynamically after each round. In this way, by performing aggregation by every cluster head in the multi-hop communication the lifetime of the network can be enhanced. Thus using data aggregation in multi-hop communication reduces data redundancy and also controls the network traffic which helps in improving the performance of the network.

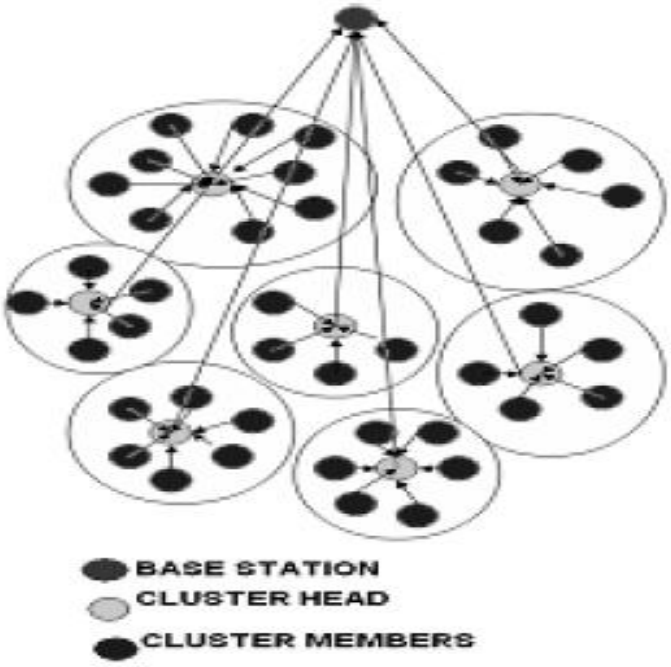


**Figure 3.3 Single Hop Communications**

In Figure 3.3 Cluster head communicating directly with sink or base station. Transmission cost is very high in single hop transmission.

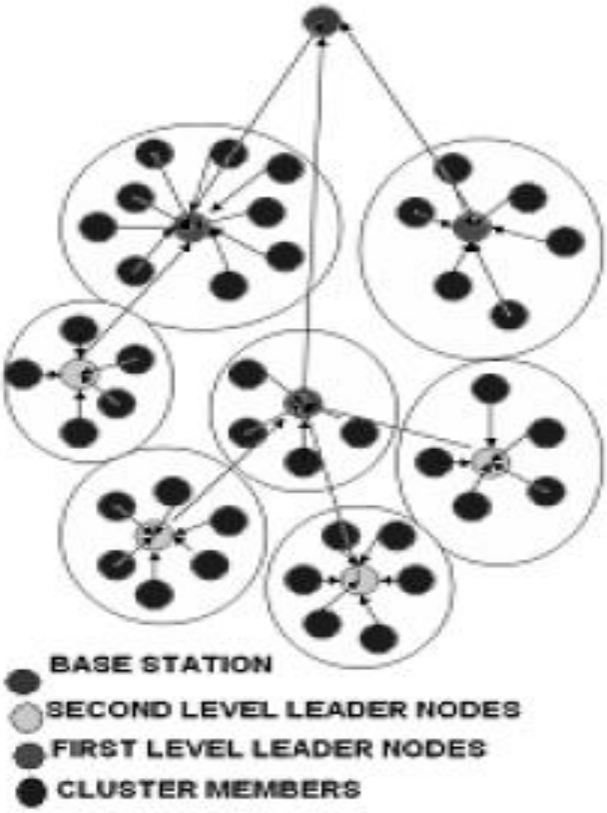


**Figure 3.4 Multi hop Inter Cluster Communication**

In multi hop communication we are transmitting the data to closest hop and it reduces the transmission cost in sensor network. We used multi hop communication in proposed algorithm to maintain the network stability.

In chapter 5 we present the simulations results of our proposed algorithm. We have created both single hop transmission and multi hop transmission networks. Cluster head takes the optimal path for data transmission which avoids the high use of transmission energy and hence increases the performance of the algorithm.

# Chapter 4 Simulation Results

We are using MATLAB 2010a to simulate our algorithm. We compared our protocol with EESAA, SEP and LEACH. We evaluate the performance on network life time and stability period of network. Compare the result on the basis of first node dead and tenth node in network. Main purpose of our algorithm to enhance the performance of Energy efficient sleep awake aware algorithm with the help of cluster head selection algorithm, Optimization of Cluster head count and multi hop inter cluster communication.

Cluster head perform data aggregation at every level to reduce the redundancy in information. We are taking several parameters to judge the correctness of algorithm.

## 4.1 Performance Measures

To evaluate the performance of this algorithm we used several parameters they are various parameter to evaluate the performance of clustering protocol:

1. *Stability Period:* -It is the period of time from start of the operation in network and till the death of first node in network and it also known as stable region.
2. *Instability Period*: - Time period between the deaths of first node to until the last node death. It is also known as unstable region.
3. *Network Life Time:* - Network life time is the time period when network start works to until the last alive node become dead.
4. *Number of Cluster Head per Round:* -When more cluster head will be occur transmission cost will also increase.
5. *Alive nodes per round:* - This parameter evaluates the how many nodes are left after each round in wireless sensor network.

Some more parameter we use to evaluate the network performance such as throughput and stability of network.

## 4.2 Network Parameters

For simulation we assume 100 m × 100 m dimension of field with 100 nodes. Position of base station is (50, 0).

| Parameter | Value |
|---|---|
| Area | 100 × 100 |
| Nodes | 100 |
| Base Station | (50,0) |
| Packet Size | 4000 *bit* |
| Initial Energy $E_0$ | 0.5 |
| $S$ | 0.1 |
| $M$ | 0.4 |
| $A$ | 1 |
| $B$ | 0.5 |
| Data Aggregation Energy $E_{da}$ | 5 *nj/bit/signal* |
| Eelec | 5 *nj/bit* |
| $\varepsilon_{fs}$ | 10 *pj/bit/m*$^2$ |
| $\varepsilon_{mp}$ | 0.013 *pj/bit/m*$^4$ |
| $p_{opt}$ | 0.1 |
| $E_s$ | $E_0(1+a)$ |
| $E_m$ | $E_0(1+b)$ |

**Table 4.1 Radio Characteristics Used in Simulation**

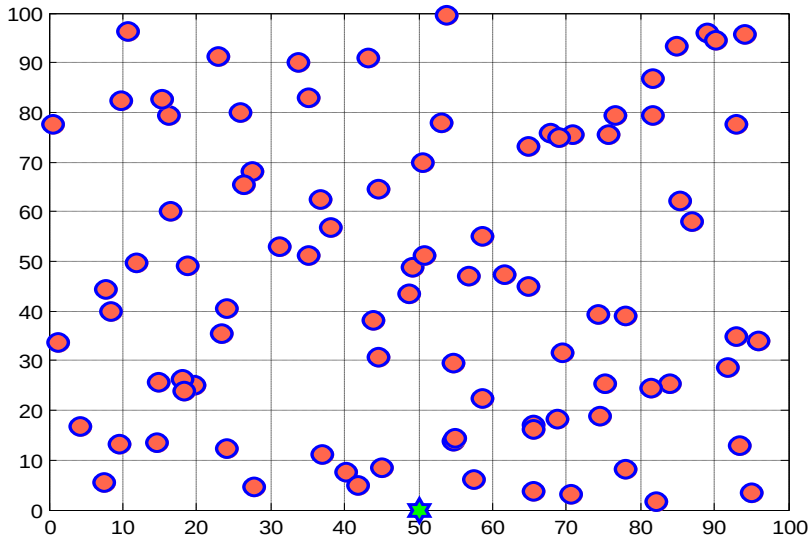


**Figure 4.1 Deployment of Nodes with Network dimension 100m × 100m and Base Station (50,0)**

In network parameter we are using several assumptions for evaluating the performance of our proposed algorithm. We are taking 100 sensor nodes and uniformly deployed in network region.

## 4.3 Data Transmission in Wireless Sensor Network

In figure 4.2 we are showing the data transmission with the help of single hop and figure 4.3 showing the multi hop communication in both of the figure only single node working when node is paired.

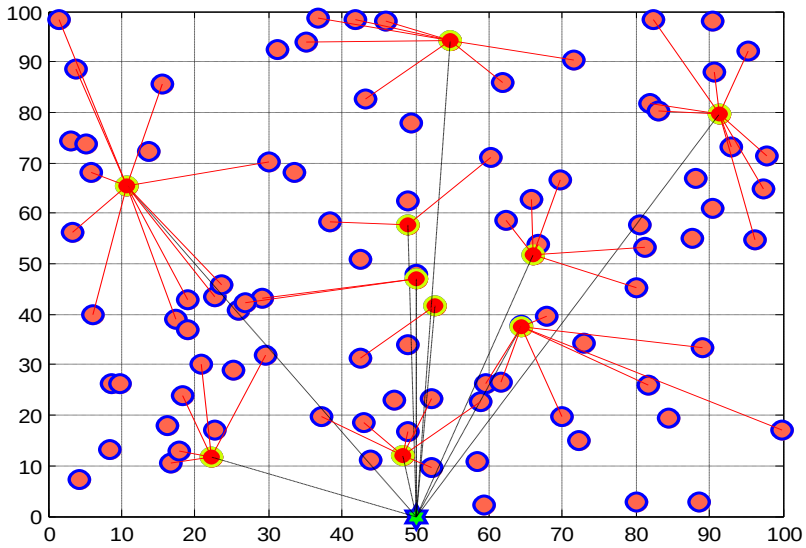


**Figure 4.2 Single hop transmissions in Network with Base station (50, 0)**

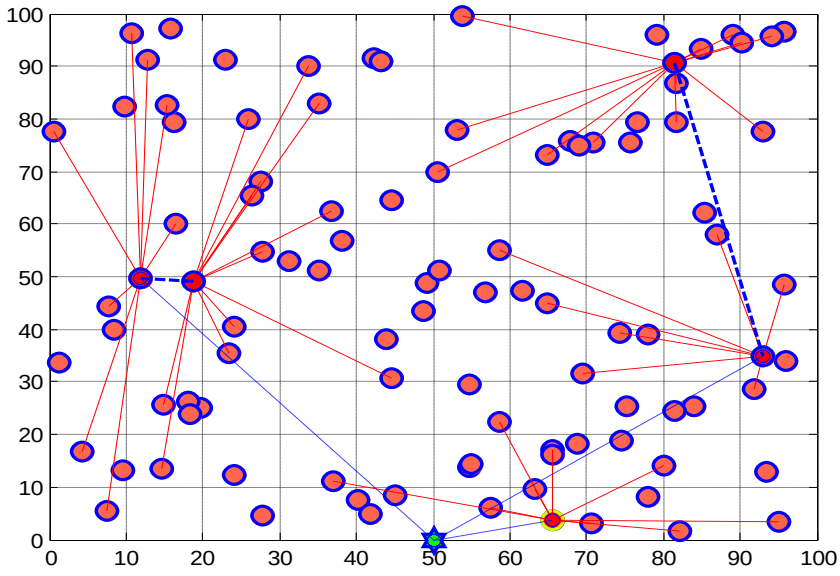


**Figure 4.3 Multi hop transmission transmissions in Network with Base station (50, 0)**

## 4.4 EECAA Algorithm Performance

In this section proposed algorithm compared the proposed algorithm with EESAA, SEP, LEACH.

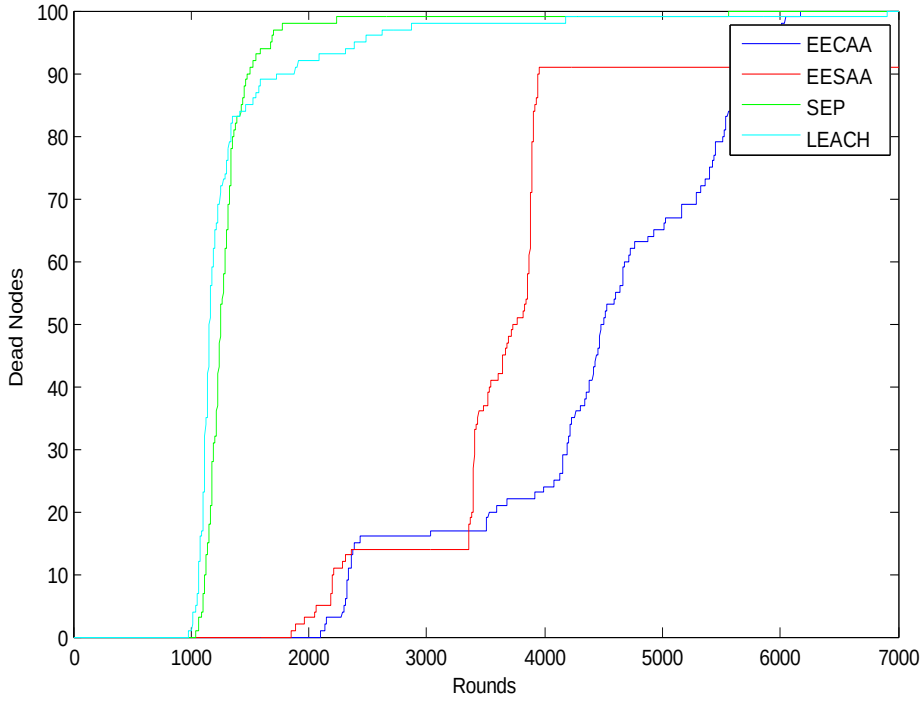


**Figure 4.4 Dead Nodes per Round and Base Station at (50, 0)**

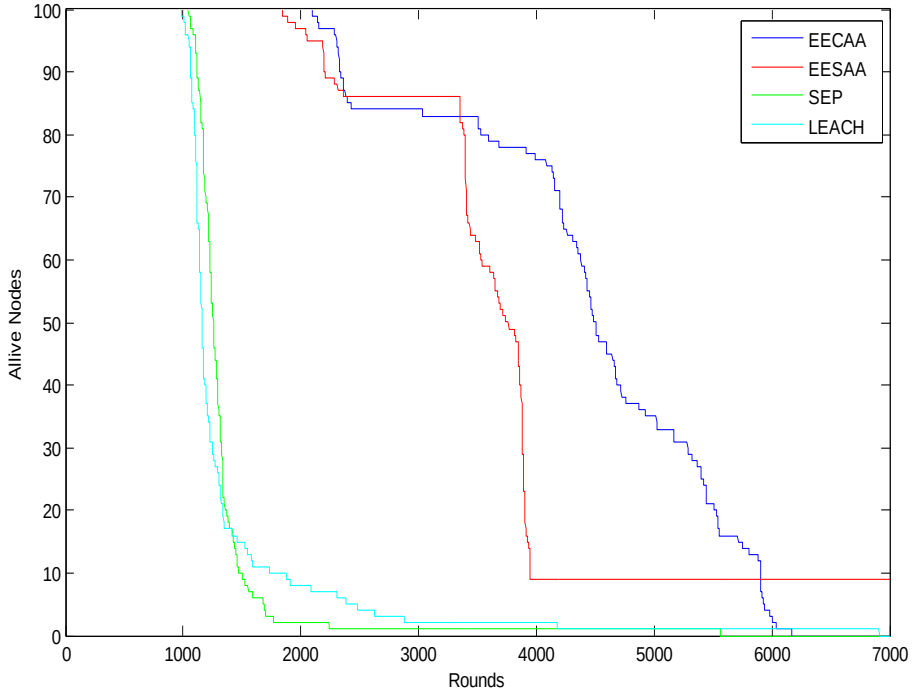


**Figure 4.5 Alive Nodes per Round and Base Station at (50, 0)**

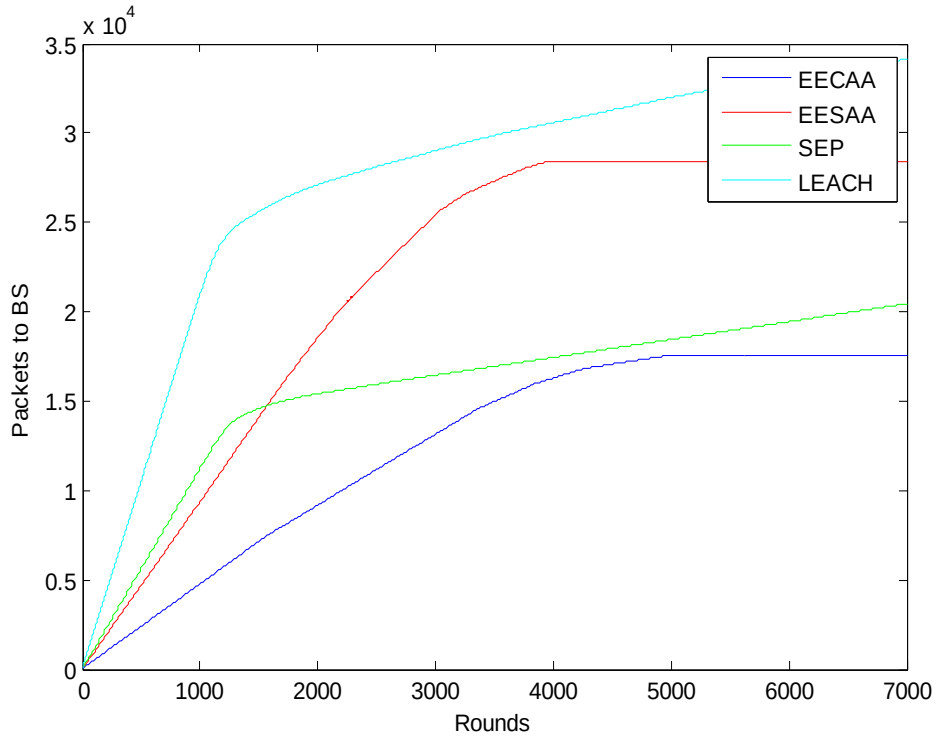


**Figure 4.6 Packets to Base Station per Round**

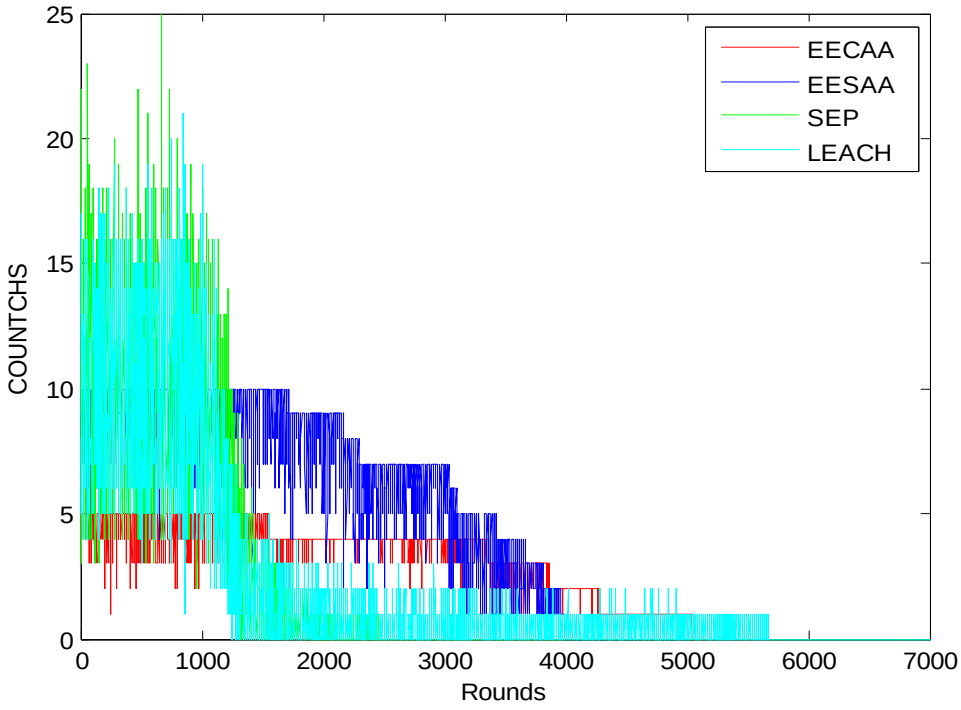


**Figure 4.7 Number of Cluster Heads per Round**

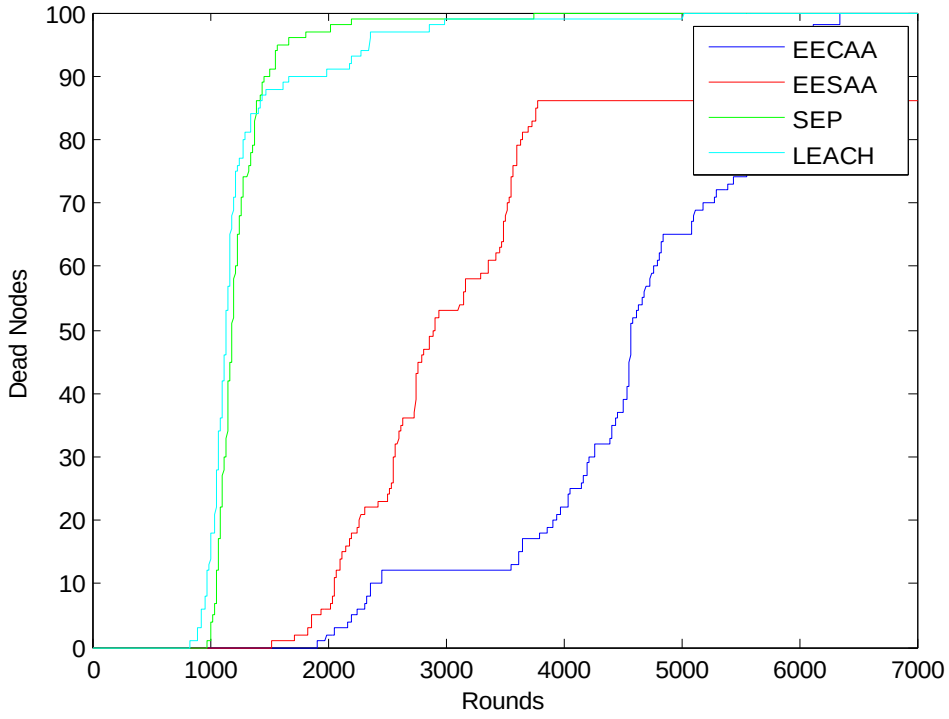


**Figure 4.8 Dead Nodes per Round and Base Station at (100,100)**

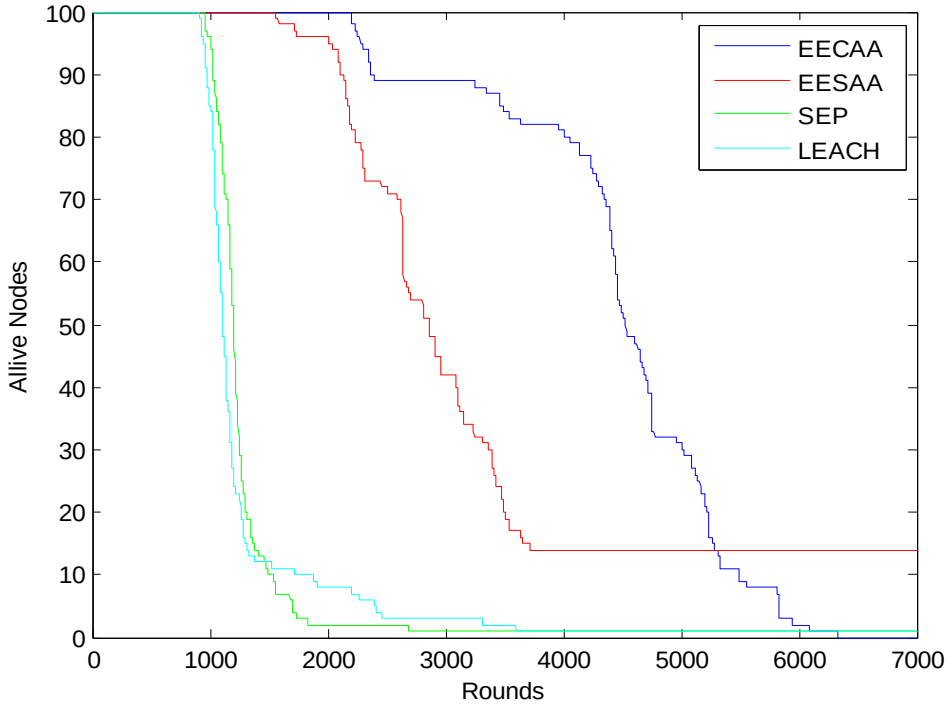


**Figure 4.9 Alive Nodes per Round and Base Station at (100,100)**

In these figures we described the performance of our algorithm. Various parameters are considered to evaluate the correctness of algorithm. Stability period of our proposed algorithm is observed to be more than traditional algorithm and is observed to be around 2100 rounds. Proposed algorithm has a better "stable region" as compare of other algorithms. Energy efficient clustering and data aggregation has also increased the life time of the network. Main purpose of this algorithm is to maximize the life time of network. We have optimised the number of CHs in our algorithm which reduces the cost of construction of excessive clusters. By optimising the number of CHs we have reduced the energy used for communication. In figure 4.6 which demonstrates the cluster head count we can see there are balanced no. of cluster heads as compared to the LEACH, SEP and EESAA. We used multi hoping concept to reduce the lengthy transmission cost and increasing the stable region. In figure 4.X we observe lesser no of packets are sent to BS as compared to other algorithms because we are using multi hop concept so every cluster head transmitting the data to nearer cluster head. Aggregation is also performed on cluster heads to remove the redundancy in the data packets received from the nodes in the clusters.

Overall proposed algorithm performed better in comparison to other algorithms and makes network more stable. EESAA algorithm is observed to perform data transmission till around 4110 rounds. Our algorithm has prolonged the network till around 6000 rounds and we can observe that our algorithm has highest lifetime as compared to other mentioned algorithms. Life time is an important factor because we cannot change sensor nodes. After 4110 rounds EESAA has only 10 nodes and they are not dying because of no transmissions. So energy is not dissipated by nodes and nodes are alive till the end but such network is useless. So we can say that these results show the enhance version of EESAA algorithm and improved the cluster head selection with optimal no. of CHs and multi-hop mode of communication. Thus our proposed algorithm increases the performance of the network and increase the lifetime keeping the energy consumed in consideration.

# Chapter 5 Conclusion and Future Scope

In recent years various applications such as tracking, monitoring, event detection use wireless sensor networks. Sensor nodes sense the environment information and send the information to base station. The various limitations attached with sensor network are limited battery, limited processing power and low bandwidth. Various researchers have proposed algorithm to preserve the energy in WSNs. Energy consumption is an important aspect in wireless sensor network because replacement of sensor nodes are impractical and the nodes cannot be recharged. Due to random deployment some nodes may be deployed close to each other and hence they sense the same redundant information which causes unnecessary increase in the transmission cost of the network.

In this thesis we proposed an energy efficient algorithm to improve the stability period and life time of the network. In this algorithm we tried to minimize the energy consumption with the help of node state, cluster head selection, optimal no. of cluster heads and optimal path from cluster heads to base station.

There is edge to improve the algorithm on the basis of the size of clusters to be optimal and equal in size to balance the energy consumption and include data compression techniques on the cluster heads with multi-hop communication to reduce and optimise the data transmission.

We improved the stable region and extend the network life time by reducing the redundancy and save the energy consumption in clustering algorithms. Optimal path is obtained which reduces the transmission cost and data aggregation is performed in our algorithm which reduces the data redundancy and preserves the energy of the network.

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