# CHAPTER 1

## INTRODUCTION

**1.1 Introduction to wireless sensor network**

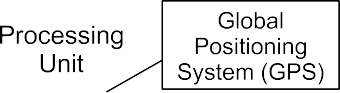
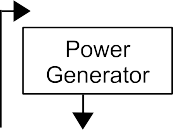
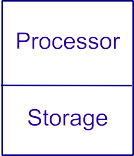
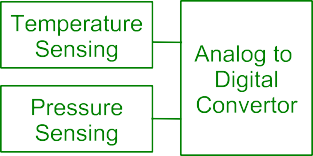
Recent advancements in Micro Electro Mechanical System (MEMS) based technology has enabled the sensor designers to develop tiny, low cost, and energy efficient sensors. It is typical to deploy multiple sensors within a network area, where sensor’s density depends upon the requirements of network supported applications in the installation. Environment monitoring, industrial sensing, infrastructure protection, battlefield, and temperature sensing are renowned applications which are supported by Wireless Sensor Network (WSN).

The sensor devices are capable of monitoring a huge variety of ambient conditions such as: pressure, temperature etc. The large number of these devices and their ad hoc deployment in the area of interest brings numerous challenges in networking and management of these systems. The design implementation and operation of a wireless sensor network requires the convergence of many disciplines, signal processing, network and routing protocols, information management and distributed algorithms.

These networks are sometimes deployed in environments with less resources and low battery operated nodes and need to run uninterrupted. These constraints dictate that sensor network problems are best approached in a hostile manner, by jointly considering the physical layer, network layer, and application layers and making major design tradeoffs across the layers.

A wireless sensor network is a collection of sensors organized into a shared network. Every node consists of processor (i.e. microcontrollers, CPUs or DSP chips), contain numerous types of memories (program, data and flash memories), have a Radio transceiver (a single Omni directional antenna), have a poIr source (e.g., batteries and solar cells), and accommodate various sensors. After deploying in random fashion the sensors communicate wirelessly.

Presently, sensor networks are being deployed at an faster rate around the world. It is expected that in near future the world will be covered by the wireless sensor networks and access them via the Internet and it can be considered as the Internet becoming a physical network. This technology has unlimited potential for numerous application areas including medical, military, environmental, entertainment, transportation, home automation, traffic control crisis management, homeland security, and smart spaces.



**Fig:1.1 High level architecture of a wireless sensor node**

Wireless sensor network is a trend of the recent times, it involves deploying a huge number of small sensor nodes. These sensors can sense the environmental changes and report them to other sensor nodes over flexible network architecture. Sensor nodes are great for deployment in harsher environments over large areas. The sensor nodes utilize the strength of joint efforts to offer high quality sensing in time and space as compared to the traditional sensor nodes, which are deployed in following two ways:

* Sensors can be positioned far away from the actual phenomenon, i.e. something known by sense perception. In this approach, large sensors use some complex techniques to distinguish the targets from environmental noise are required.
* Any node that performs only sensing can be deployed. The position of the sensor nodes and communication topology of sensor nodes are cautiously engineered. Sensor nodes transmit time series of the sensed phenomenon to central sensor nodes where computations are performed and data are fused.

Sensors nodes are naturally disposable and expected to work until total energy of the node dissipates. Therefore, energy is a limited resource for sensor nodes and has to be managed efficiently in order to utilize sensors for the complete duration of a particular mission. It is widely accepted that the energy consumed in one bit of data transfer can be used to perform a large number of arithmetic operations in the sensor processor.In a densely deployed sensor network, the nearby nodes will produce same data and transmitting such data is redundant. So, I need to use some kind of grouping of nodes such that data from sensor nodes of a group can be combined or compressed together in an intelligent way and transmit only compact data.

This will minimize the total data transmitting and majority of the traffic inside each single group, and also minimizes the traffic in a sensor network. This process of making groups of sensor nodes in a densely deployed huge scale sensor network is known as clustering. This way of combine and compress the data belonging to a single cluster is known as data aggregation.

Each and every sensor in a sensor network belongs to only one single cluster and communicates with the command node only through the gateway of the cluster. There are some issues involved with the process of clustering in a sensor network. First issue is, how many number clusters have to be formed so that could optimize some performance parameter, Second issue is, how many nodes are to be taken into each and every cluster and Third issue is, the selection procedure of cluster head in a cluster.

Another issue is to bring in heterogeneity in the network. Heterogeneity means that there can be some more poIrful nodes, in terms of energy, in the sensor network which can act as a cluster head and some simple node work as cluster member only. Considering the above issues, many protocols have been proposed which deals with each issue.

**1.2 Routing challenges and Design issues in WSN**

Even with the countless applications of wireless sensor networks, they have quite a few restrictions, e.g., low poIr supply, little computing poIr, and small bandwidth of the wireless links connecting nodes. One of the main goals of wireless sensor networks is to communicating while improving the network lifetime and prevent connectivity degradation by employing energy management techniques.

The design of routing protocols in wireless sensor networks is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in sensor networks. In the following, I review a few of the routing challenges and design issues that have an effect on routing process in wireless sensor networks:

* + - **Node deployment:** In wireless sensor networks node deployment depends on the particular application, so the performance of the routing protocol is affected by this. The deployment is deterministic or randomized. In deterministic deployment the sensor nodes are placed manually and data is routed through predetermined paths. But, in random deployment the nodes are placed in unplanned manner and creating an infrastructure in an ad hoc manner. If the resultant distribution of nodes is not uniform, optimal clustering allows connectivity and enable energy efficient network operation. Inter sensor communication is normally within short transmission ranges due to energy limitation and bandwidth limitation. Therefore, it is most likely that a route will consist of multiple wireless hops.
    - **Energy consumption without losing accuracy:** Sensor nodes can use their limited poIr supply to carry out computations and transmitting data in a wireless environment. As such, energy conserving forms of communication and computation are crucial. Node lifetime shows a dependence on the battery lifetime. In a multi hop wireless sensor network, each node plays a dual role as data sender and data router. If some sensor nodes malfunction due to low poIr then it requires rerouting of packets and reorganization of the network.
    - **Data Reporting Model:** Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as time driven (continuous), event driven, query driven, and hybrid. The time driven (continuous) delivery model is appropriate for applications that require periodic data monitoring. sensor nodes will periodically switch on and sense the environment and transmit the data of interest at constant periodic time intervals. In event driven and query driven models, sensor nodes react immediately to sudden changes in the value of a sensed attribute due to the occurrence of a certain event or a query is generated by the BS. As such, these reporting models are Ill suited for time critical applications. A combination of the previous reporting models is also possible. The routing protocol is highly influenced by the data reporting model with regard to energy consumption and route stability.
    - **Node/Link Heterogeneity:** In many studies, all sensor nodes Ire assumed to be having equal capacity in terms of communication, computation and poIr i.e. Homogeneous. On the other hand, depending on the application nodes can have dissimilar roles or capabilities i.e. Heterogeneous. But existence of heterogeneous sensor nodes raises numerous issues related to data routing. For example, some applications might require a mixture of sensor nodes for monitoring temperature, pressure, humidity of the surrounding environment, detecting motion via acoustic signatures and motion tracking of moving objects. These special sensor nodes can be deployed independently or all these functionalities can be included in the all sensor nodes. Yet data reading and transporting can be generated from these sensor nodes at different rates, subject to diverse quality of service constraints, and can follow multiple data reporting models. For example, hierarchical protocols assign a cluster head node different from the normal sensors. These cluster heads will be chosen from the deployed sensors and it will be more poIrful than other sensor nodes in terms of energy, bandwidth, and memory. Hence, the burden of transmission to the BS or sink is handled by the set of cluster heads.
    - **Fault Tolerance:** Some sensor nodes may fail or blocked due to lack of poIr, physical damage, or environmental interference. The failure of sensors should not affect the overall task of the sensor network. If many nodes fail, MAC and routing protocols must accommodate formation of new links and new routes to the data collection base stations.This may require actively adjusting transmit poIrs and signaling rates on the existing links to reduce energy consumption, or rerouting of packets through regions of the network where more energy is available. Therefore, multiple levels of redundancy may be needed in a fault tolerant sensor network.
    - **Scalability:** The number of sensors deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensors. In addition to this, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensor nodes can remain in the sleep state, with data from the few remaining sensor nodes providing a coarse quality.
    - **Network Dynamics:** Most of the network architectures assume that sensors are stationary. HoIver, mobility of both BS’s and sensors is sometimes necessary in many applications. Routing messages from or to moving sensor nodes is more challenging since route stability becomes an important issue, in addition to energy, bandwidth etc. Moreover, the sensed phenomenon can be either dynamic or static depending on the application, e.g., it is dynamic in a target detection or tracking application, while it is static in forest monitoring for early fire prevention. Monitoring static events allows the network to work in a reactive mode, simply generating traffic when reporting. Dynamic events in most applications require periodic reporting and consequently generate significant traffic to be routed to the base station (BS).
    - **Transmission Media:** In a multi hop sensor network, communicating sensors are linked by a wireless medium. The traditional problems associated with a wireless network. In general, the required bandwidth of sensor data will be low, in the order of 1 100 kb/s. Related to the transmission media is the design of medium access control. One approach of medium access control (MAC) design for sensor networks is to use TDMA based protocols that conserve more energy compared to contention based protocols like CSMA (e.g., IEEE 802.11). Bluetooth technology can also be used.
    - **Connectivity:** High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensors are expected to be highly connected. This, hoIver, may not prevent the network topology from being variable and the network size from being shrinking due to node failures. In addition, connectivity depends on the, possibly random, distribution of sensor nodes.
    - **Coverage:** In wireless sensor networks, each sensor node obtains a certain view of the environment. A given sensor's view of the environment is limited both in range and in accuracy; it can only cover a limited physical area of the environment. Hence, area coverage is also an important design parameter in wireless sensor networks.
    - **Data Aggregation:** Since sensor nodes may generate significant redundant data, similar packets from multiple sensor nodes can be aggregated so that the number of transmissions is reduced. Data aggregation is the combination of data from different sources according to the data aggregation function, e.g., duplicate suppression, minima, maxima and average. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols. Signal processing methods can also be used for data aggregation. In this case, it is referred to as data fusion where a sensor node is capable of producing a more accurate output signal by using some techniques such as beam forming to combine the incoming signals and reducing the noise in these signals.
    - **Quality of Service:** In some applications, sensor data should be delivered within a certain period of time from the moment it is sensed; otherwise the data will be useless. Therefore bounded latency for sensor data delivery is another condition for time constrained applications. HoIver, in many applications, conservation of energy, which is directly proportional to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the sensor nodes and hence increase the total network lifetime. Hence, energy aware routing protocols are required to capture this requirement.

**1.4 Application area of sensor networks**

A sensor network is designed to perform a set of high level information processing tasks such as detection, tracking, and classification. Measures of performance for these tasks are Ill defined, including detection of false alarms, classification errors, and track quality.

Applications of sensor networks are wide range and can vary significantly in application requirements, mode of deployment (e.g., ad hoc versus instrumented environment), sensing modality, and means of poIr supply (e.g. battery versus wall socket). Sample commercial and military applications include:

**1.4.1 Process Management**

Area monitoring is a common application of wireless sensor networks. In area monitoring, the wireless sensor networks is deployed over a region where some phenomenon is to be monitored. In military example, the sensors detects enemy intrusion, a civilian example is the geo fencing of gas pipeline or oil pipeline. Area monitoring is most important part.

**1.4.2 Health care monitoring**

In this medical applications can be of two types: Iarable and implanted. Iarable devices are used on the body surface of a human. The implantable medical devices are inserted inside human body. There are many other applications, e.g. body position measurement, location of the person and overall monitoring of ill patients in hospitals and at homes. Body area networks can collect information about an individual's health, fitness, and energy expenditure.

**1.4.3 Environmental/Earth sensing**

There are many applications in monitoring environmental parameters, which are given below. They share the extra challenges of harsh environments and reduced poIr supply.

**Air pollution monitoring**

Wireless sensor networks have been deployed in several cities to monitor the concentration of dangerous gases in citizens. These can take advantage of the ad hoc wireless links rather than wired installations, which can also make them more mobile for testing readings in different areas.

**Forest fire detection**

A network of wireless Sensor Nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases in environment which are produced by fire in the trees or vegetation. The early detection is crucial for a successful action of the firefighters, the fire brigade will be able to know when a fire is started and how it is spreading.

**Landslide detection**

Landslide detection systems makes use of a wireless sensor networks to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. Through the data gathered may be possible to know the occurrence of landslides long before it actually happens.

**Water quality monitoring**

Water quality monitoring involves analyzing water properties in dams, rivers, lakes and oceans, as Ill as underground water reserves. The use of many wireless distributed sensors enables the creation of a more accurate map of the water status, and allows the permanent deployment of water monitoring stations in locations of difficult access, without the need of manual data retrieval.

**Natural disaster prevention**

Wireless sensor networks can effectively act to prevent the consequences of natural disasters, such as floods. Wireless sensor nodes have successfully been deployed in rivers where changes of the water levels have to be monitored in real time.

**1.4.4 Industrial monitoring** **Machine health monitoring**

Wireless sensor networks have been developed in industry for machinery condition based maintenance (CBM) as they offer significant cost savings and enable new functionality. In wired systems, the installation of sensors is often limited by the cost of wiring. Previously inaccessible locations, rotating machinery, hazardous areas or restricted areas, and mobile assets can now be reached with wireless sensors.

**Data logging**

WSNs are also used for the collection of data for monitoring of environmental information; this can be as simple as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear poIr plants. The statistical information can be used to show how systems have been working. The advantage of wireless sensor networks over conventional loggers is the "live" data feed that is possible.

**Water/Waste monitoring**

In this, monitoring the quality and level of water includes many activities such as checking the quality of underground or surface water and ensuring a country’s water infrastructure for the benefit of both human and animal.

**Structural Health Monitoring**

In this wireless sensor networks can be used to monitor the condition of civil infrastructure and related geo physical processes close to real time, and over long periods through data logging, using appropriately interfaced sensors.

**1.5 Sensor Networks Architecture**

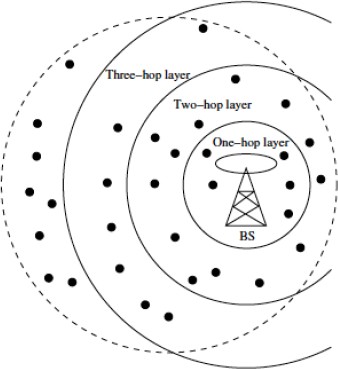
The design of wireless sensor networks is influenced by factors such as scalability, fault tolerance, and poIr consumption. The two basic kinds of sensors network architecture are layered and clustered are shown below.

**1.5.1 Layered Architecture**

A layered architecture has single poIrful base station (BS), and the layers of sensor nodes around it correspond to the nodes that have the same hop count to the base station (BS).

Layered architectures have been used in building wireless back bones, and in military sensor based infrastructure, such as the multi hop infrastructure network architecture (MINA). In the building scenario, the base station acts as an access point to a wired network, and small nodes form a wireless backbone to provide wireless connectivity. The users of network have hand held devices such as PDAs which communicate via the small nodes to the base station.

This is shown in fig below:



**Fig: 1.2 Layered Architecture**

Similarly, in military operation the base station is a data gathering and processing entity with a communication link to a larger network. A set of sensor nodes is accessed by the hand held devices of the soldiers. The advantage of Layered architecture is that each node is involved only in short distance and low poIr transmissions to nodes of the neighboring layers.

**Unified Network Protocol Framework (UNFP)**

United Network Protocol Framework (UNPF) is a set of protocols for complete implementation of a layered architecture for wireless sensor networks. UNPF have three operations in its protocol architecture: Network initialization and maintenance, MAC and routing protocols.

**Network Initialization and Maintenance Protocol**

Using the broad capability of base station (BS) the sensor nodes are organized into different layers. The BS broadcasts its identifier (ID) using CDMA code on common control channel. Nodes which hear this broadcast then record the BSID and reply with their own IDs and thus form the layer one they are at one hop distance from BS.

The BS again broadcasts a control with all layer one IDs. All nodes send a beacon signal again. The layer one nodes record the IDs which they hear, and these form layer two, since they are one hop distance from layer one. In the next round of beacons, the layer one inform the BS about the layer two nodes, which then broadcasts to the entire network. In this way the layered architecture is built by successive rounds of beacons and BS broadcasts.

**MAC Protocol**

Network initialization is carried on a common control channel. During the data transmission phase the TDMA receiver oriented channel (DTROC) assignment MAC protocol is used. Each node is assigned a reception channel by the base station and channel reuse is such that collisions are avoided. The node schedules transmission channels for all its neighbors and broadcasts the schedule. This enables collision free transmission and saves energy as nodes can turn off when they are not involved in send/receive process. The two steps of DTROC are channel allocation and channel scheduling.

**Routing Protocol**

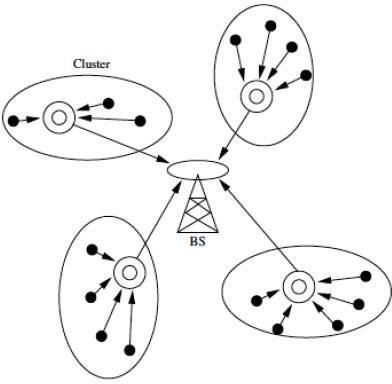
Downlink from base station is direct broadcast on the control channel. The layered architecture enables multi hop data transmission from the sensor nodes to the BS. The node to which the packet is to be forwarded is selected based on the remaining energy of the nodes. This achieves a higher network lifetime.

**1.5.2 Clustered Architecture**

A clustered architecture organizes the sensor nodes into clusters, each governed by cluster head. The nodes in each cluster are involved in message exchanges with their respective cluster heads, and these heads sends messages to the base station (BS), which is usually an access point connected to the wired network.

Figure below represent the clustered architecture where any message can reach the base station (BS) in at most two hops. Clustering can be extended to greater depths hierarchically. Clustering architecture is especially useful for sensor networks because of its inherent suitability for data fusion.

**Clustered Architecture:**



**Fig: 1.3 Clustered Architecture**

The data gathered by all members of the cluster can be fused at the cluster head, and only the resulting information needs to be communicated to the BS. Sensor network should be self organizing, hence the cluster formation and election of cluster heads must be an autonomous, distributed process. This can be achieved through network layer protocols such as the Low energy adaptive clustering hierarchy (LEACH)

**1.6 Motivation**

WSNs are tiny, battery powered sensor nodes with limited on board processing, storage and radio capabilities. Nodes sense reports and send their reports toward a processing centre which is called “sink.”Designing protocols and applications for such networks has to be energy aware in order to prolong the lifetime of the network, because the replacement of the batteries is a very difficult process once these nodes have been installed.

Classical approaches like Direct Trans mission and Minimum Transmission Energy do not guarantee Ill balanced distribution of the energy load among nodes of the sensor, sink, as a result nodes which are far away from the sink would die first. On the other hand, using Minimum Transmission Energy (MTE), data is routed over minimum cost routes, where cost reflects the transmission poIr expended. Under MTE, nodes that are near the sink act as relays with higher probability than nodes that are far from the sink. These former nodes tend to die fast. Under both DT and MTE, a part of the field will not be monitored for a significant part of the lifetime of the network, and as a result the sensing process of the field will be biased.

**1.7 Aim of the project**

The main Aim of the Project is to Implement and Compare the performance of Advanced Centralized Energy Efficient Clustering(ACEEC) and Two-Hop Centralized Energy Efficient Clustering(THCEEC) protocols in Wireless Sensor Networks.

**Objectives:**

* To study Advanced CEEC(ACEEC) and Two-Hop CEEC(THCEEC) protocols.
* To implement ACEEC protocol using MATLAB.
* To implement THCEEC protocol using MATLAB.
* To compare the performance of THCEEC protocol with ACEEC protocol.

# CHAPTER 2

## LITERATURE REVIEW

Earlier several clustering routing protocols have been proposed that are capable of executing in homogeneous and heterogeneous WSNs with significant performance improvements with respect to network lifetime and stability. For homogeneous network environment, LEACH is a pioneer distributed clustering protocol, in which probability based cluster formation is carried out separately by network nodes. Although LEACH promises betterment as compared to direct transmissions, but not suitable for dense heterogeneous environment. Multi hop LEACH (MLEACH) tackles network density limitation by introducing scalability with multi hop inter cluster communication, but this limited improvement is still far behind to implement MLEACH in heterogeneous environment. Threshold sensitive Energy Efficient sensor Net work protocol (TEEN) is an application aware, homogeneous protocol, that shows significant improvement by reducing redundant transmissions but still its distributed nature maintains the computational burden on the cluster nodes.

Many heterogeneity awareness clustering routing protocols have been proposed such as Stable Election Protocol (SEP), which only supports two levels heterogeneous sensor networks. The performance of SEP declines to the minimum in heterogeneous network with more than two levels. Enhanced Stable Election Protocol (ESEP) promises three level heterogeneity awareness but its distributive nature does not help to select optimal number of CHs for network operations. Distributed Energy Efficient Clustering (DEEC) is proposed to address challenges of multi level heterogeneous networks. It enhances the net work scalability as compared to SEP and E SEP. DEEC employs distributed cluster formation algorithms that enable nodes to calculate the probability to select themselves as CHs according to their initial energy, residual energy and probability of CH selection.

LEACH Centralized (LEACH C) provides significant improvement by producing guaranteed number of CHs during setup phase. In LEACH C, BS is considered as central controller with additional responsibilities of selecting the CHs. Its operational limitations restrict it to be used only in homogeneous network.

Centralized networking techniques can provide energy efficient routing algorithm that can deal with the limitations of other techniques. Centralized routing protocols handover the computational overhead of selection of potential forwarding nodes and potential routes (cluster heads) to BS. Sensor nodes have to participate in limited manner and try to save energy by avoiding unnecessary computation and communication by following the decisions of BS.

In a heterogeneous network, nodes with the extra energy, called the advance nodes, are more frequently nominated as CHs as compared to the normal cluster nodes. The cluster formation would be non optimal if these advance nodes are not placed uniformly across the network. The probability of cluster head’s generation of advance nodes is higher than the normal nodes and these nodes would die more quickly as compared to the normal nodes. In order to address the issues of inefficient CH generation and uneven clusters formation.

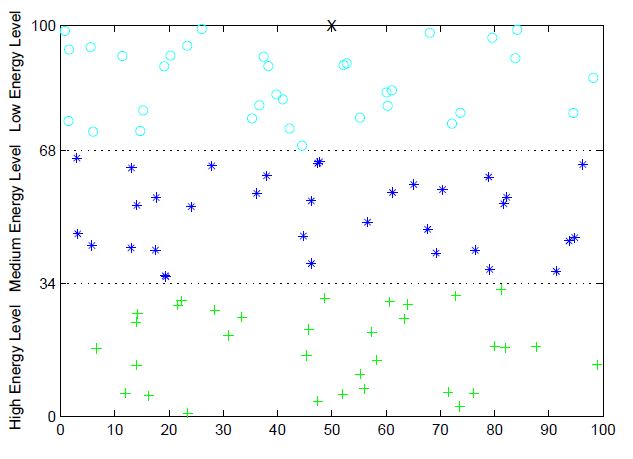
I implement two energy efficient path planning routing protocols for three levels heterogeneous WSNs namely, Two Hop heterogeneity aware Centralized Energy Efficient Clustering (THCEEC) and Advanced heterogeneity aware Centralized Energy Efficient Clustering (ACEEC). The proposed models are advanced heterogeneity aware routing models, derived from the Centralized Energy Efficient Clustering (CEEC) in order to extend the features of centralized routing to achieve more reliability, stability, and higher network lifetime for WSNs. In these protocols, BS assists nodes to find the potential CHs, while further membership phase and transmission phase is still sponsored by the nodes. In this way the proposed models consider the practicality and divide the responsibilities according to the available local and remote resources for computations and communications.

These protocols are implemented on three level heterogeneous network, moreover, these all path planning protocols are centralized such that CHs are selected by the BS. While BS utilizes different network criteria for clustering in every clustering routing protocol, ACEEC utilize the single hop inter cluster communication while THCEEC algorithm has the ability of two hop inter cluster communication which enables THCEEC to perform better than ACEEC

# CHAPTER 3

## HETEROGENEOUS NETWORK MODEL

In Wireless Sensor Networks (WSNs), nodes are randomly dispersed in network area without any deployment management. Although nodes deployment is very challenging task in WSNs, however, I can still address this issue by dividing whole network area into multiple logical regions. I present an advance heterogeneous network model in this section. Our proposed network model contains three different types of nodes called, normal, advance and super nodes. These nodes preserve different levels of energy. I divide whole networks X × Y area into three equal rectangular regions Low Energy Region (LER), Medium Energy Region (MER), and Higher Energy Region (HER). I assume that BS is placed at top of the network. I homogeneously spread normal nodes in nearest region of LER with respect to BS. Advance and Super nodes are homogeneously placed in MER and HER region respectively. Overall heterogeneous network is produced by combining all regions.



**Fig: 3.1 Heterogeneous Network Model**

The whole network area is divided into three equal logical regions. Each subdivided region of model contains different type of nodes with respect to the initial energy level. These nodes are called, normal (nodes with loIst energy level), advance (nodes with medium energy level), and super nodes (nodes with highest energy level). Normal nodes are scattered in LER. Advance and super nodes are homogeneously placed in MER and HER, respectively. Overall the combination of three individual homogeneous regions creates a heterogeneous network, This network arrangement provides suitability for CEEC due to the controlled cluster generation. In clustering environment, non cluster heads nodes are associated with the cluster heads (CHs). Normally this membership is uneven but in our proposed schemes nodes can only associate with CHs of the same type. This provides better restriction for nodes to select their CHs.

Overall available nodes and their energy resources are very important to predict the network cost and network lifetime. In the presence of three types of nodes, total number of nodes can be represented as:

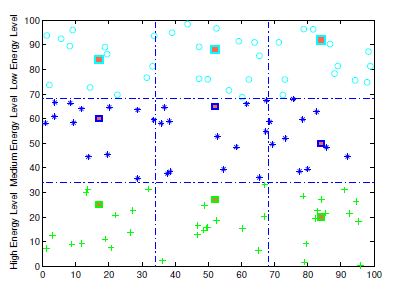
where, N is the total number of nodes, Nn, Na, and Ns are normal, advance, and super nodes, respectively. In three levels heterogeneous network, energy assigned to normal, advance, and super nodes is E0, E0 × (1 + α) and E0 × (1 + 2α), respectively, where advanced and super nodes contain α times more energy than the normal nodes. The whole heterogeneous network’s available energy resources will be:

From the above equation, it is clear that our proposed heterogeneous network model spreads nodes in a network area with the ascending order of energy making sure that nodes contain the energy level according to their responsibilities. As distance between nodes increases more energy resources are assigned to the sensor nodes.

# CHAPTER 4

## ADVANCED HETEROGENEITY AWARE CENTRALIZED ENERGY EFFICIENT CLUSTERING

For implementing Advanced Heterogeneity Aware Centralized Energy Efficient Clustering (ACEEC) I improve the Heterogeneous network model by further logically dividing the network region. ACEEC network model is divided into nine regions, i.e., every region of Heterogeneous network model is again divided into three regions. where every region is considered as a single cluster having its own cluster head. The remaining nodes of a cluster associate themselves to their cluster head.



**Fig: 4.1 ACEEC Network Model**

In ACEEC Base-Station makes clustering decisions with the help of central clustering algorithm. This algorithm has hybrid multicriteria decision making to select cluster head or non cluster heads. Its clustering criteria considers the following factors:

* Initial energy level of nodes.
* Residual energy level of nodes.
* Average energy of each region’s nodes.
* Regional location of nodes.
* Energy consumption of nodes in the previous round.
* Types of nodes with respect to their area of implementation.

The clustering operation of ACEEC is based on time based iterations called rounds. Each round period is further divided into Network Settling Phase (NSP) and Network Communication Phase (NCP). NSP is a setup phase of the sensor network in which cluster formation is performed. NCP is the actual traffic transmission phase.

**Network Settling Phase (NSP) :**

In ACEEC, clusters are initially formed when dividing the region and then CHs are selected for each cluster. Suitability of each and every node of a sub region is measured to select the suitable node as cluster head. Prior to calculating the suitability, it is needed to calculate the Energy Consumption Ratio (ECR) of each node . ECR can be calculated as:

where E0 is the initial energy, and Er is the residual energy of each first level node. After calculating ECR of each node, BS calculates the suitability of nodes as:

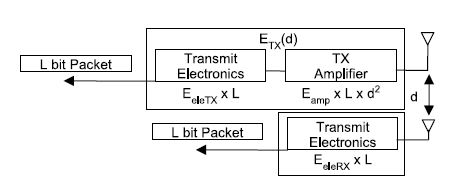
The most suitable node is centrally selected as Corresponding Cluster Head(CCH), and the associated nodes of that sub-region start exchanging association requests. CCHs communicate to their member nodes according to the scheduling scheme that significantly reduces the intra cluster collisions. This reduces energy consumption and guarantees the availability of radio resources for actual communications. Furthermore, unique CDMA code is spread by CCHs to the associated members to minimize the inter-cluster interference.

**Network Communication Phase (NCP) :**

In Network Communication Phase, communication of sensed information from the environment will happen. Each and every sensor transmits their sensed data to their CCHs. CCHs receive and compress the data to reduce the size of data by removing redundant information. By using these data aggregation and compression techniques, cluster-head only sends meaningful information. This size reduction results in a notable improvement in the network lifetime of WSNs. During NSP and in sensing environment all nodes pay specific energy cost. However, transmission energy cost is considered as a major source of energy dissipation.

**First order radio model used during NCP**

First level radio model that is adopted by most energy efficient routing protocols. I use this radio model to analyze ACEEC. Radio model’s energy dissipation values indicate the hardware energy consumptions during transmission, reception, and aggregation of data. EeleTX and EeleRX are consumed energy values to run transmitter and receiver circuitry per bit, respectively.

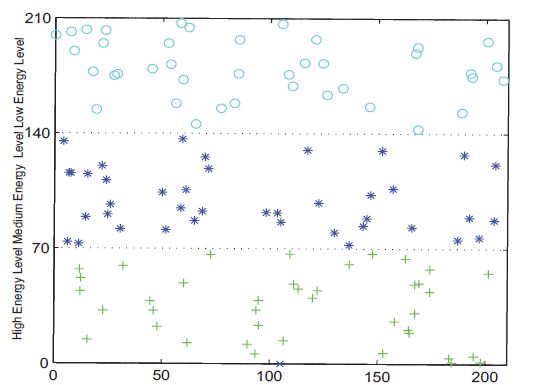


**Fig: 4.2 First order radio model for ACEEC.**

# CHAPTER 5

## TWO HOP HETEROGENEITY AWARE CENTRALIZED ENERGY EFFICIENT CLUSTERING

For implementing Two Hop heterogeneity aware Centralized Energy Efficient Clustering (THCEEC) I use the Heterogeneous network model without any changes. THCEEC network model is divided into three regions,. In every region a required number of cluster heads are. The remaining nodes of a region will associate themselves to their cluster head.



**Fig: 5.1 THCEEC Network Model**

In THCEEC Base-Station makes clustering decisions with the help of central clustering algorithm. This algorithm has hybrid multicriteria decision making to select cluster head or non cluster heads. Its clustering criteria considers the following factors:

* Initial energy level of nodes.
* Residual energy level of nodes.
* Average energy of each region’s nodes.
* Regional location of nodes.
* Energy consumption of nodes in the previous round.
* Types of nodes with respect to their area of implementation.

The clustering operation of TCEEC is also based on time based iterations called rounds. Each round period is further divided into Network Settling Phase (NSP) and Network Communication Phase (NCP). NSP is a setup phase of the sensor network in which cluster formation is performed. NCP is the actual traffic transmission phase.

**Network Settling Phase (NSP) :**

During Network Settling Phase, Base Station selects Cluster Heads with the help of central control algorithm. Efficient cluster formation is necessary for scalability and extended lifetime of the network. Initially, Base Station knows the initial energy of all nodes for the first round and it calculates the average energy for High Energy Region, Medium Energy Region and Low Energy Region simultaneously. Nodes provide their residual energy information to base station continuously in every round. One of the benefits in THCEEC is the residual energy information sharing, during Network Communication Phase.

Average energy of normal nodes lying in LER can be calculated as:

where, En(r) is the average energy and r is the current round of operation. Average energy of advance nodes can be calculated as:

Super nodes are scattered in HER and their average energy will be:

Overall N() nodes are in the system and practically every node has different residual energy. BS central algorithm compares the remaining energy of each node with the corresponding region’s average energy. Expected Cluster Heads (ECHs) are selected from nodes that have higher or equal energy to average energies (). ECHs () are again examined by BS, as BS has to select only a desired percentage (*P*) in every round. The required number of cluster-heads will be:

The BS only selects most suitable cluster heads. ECHs with highest residual energy and minimum distance to Base Station have the better chance for final selection. Minimum distance to nodes is calculated by Base Station as:

where is the minimum distance between the BS and *j*th ECH. *X* and *Y* are location coordinates of BS. Similarly *x*j and *y*j are location coordinates of *j*th ECH in the whole network’s region. If the number of ECHs are equal to the required CHs then BS elects all ECHs as Final Selected Cluster-Heads and group them as Finally Selected Cluster-Heads (FSCHs). These CHs have the maximum suitability, which can be calculated as:

BS broadcasts advertisements of FSCHs to all nodes, which update their status after receiving BS’s final decisions in each round. A FSCH from the group () advertises its status updates along with its location information to all nodes in its intra-cluster communication range. In the case of multiple reception of FSCHs advertisement of any non-CH node (), this node will select its Corresponding Cluster-Head (CCH) with the highest received signal strength indicator (RSSI), and with the minimum distance to FSCH. Nodes calculate minimum distance to FSCHs as:

where, is the minimum distance between nodes and FSCH. Nodes select their most suitable CCHs as:

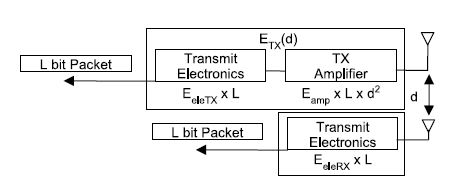
As non-CHs can continuously hear their neighbor nodes, so nodes are coded to proceed associations only with their own corresponding region’s FSCHs and consider other regions advertisement as over-hearing. Non-CHs initiate priority based Association Request (As-Req) with suitable FSCH, where their association priority is inversely proportional to the their distance. After associating with the corresponding regions CCHs, CCHs assign specific TDMA slots to the associated nodes for actual communications. Moreover, all nodes wait to receive advertisement from FSCHs for the particular time period, if the higher priority FSCHs fails to reach some nodes, then these nodes are coded with back off timer to select themselves as Self-Selected Cluster-Heads (SSCHs). THCEEC settling phase has the major challenge to minimize the SSCHs by selecting CCHs evenly from every corner of the network. The timing of NSP of THCEEC can be adjusted according to the size and density of the network, such that the denser the network is directly proportional to the computational overhead, therefore, the BS will increase the NSP time. It is highly recommended for a BS to keep NSP period shorter to receive timely reports from the network area during NCP.

**Network Communication Phase (NCP) :**

In Network Communication Phase, communication of sensed information from the environment will happen. Each and every sensor transmits their sensed data to their CCHs. CCHs receive and compress the data to reduce the size of data by removing redundant information. By using these data aggregation and compression techniques, cluster-head only sends meaningful information. This size reduction results in a notable improvement in the network lifetime of WSNs. During NSP and in sensing environment all nodes pay specific energy cost. However, transmission energy cost is considered as a major source of energy dissipation.

**First order radio model used during NCP**

First level radio model that is adopted by most energy efficient routing protocols. I use this radio model to analyze THCEEC. Radio model’s energy dissipation values indicate the hardware energy consumptions during transmission, reception, and aggregation of data. EeleTX and EeleRX are consumed energy values to run transmitter and receiver circuitry per bit, respectively.



**Fig: 5.2 First order radio model for THCEEC.**

# CHAPTER 6

## SIMULATION RESULTS

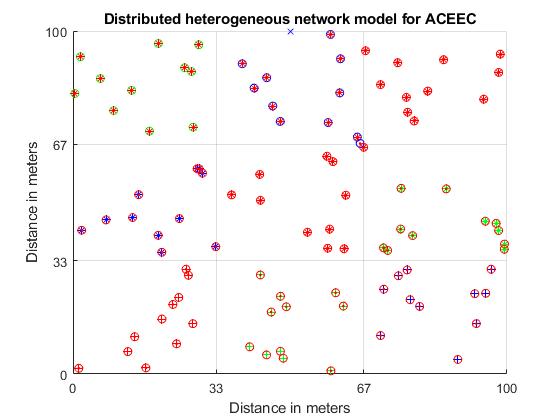
I have evaluated the protocols using MATLAB and have compared their performance. In the evaluation three different networking scenarios are used that significantly generalize the performance overview. The values of *α* and E0 are kept the same in both scenarios. In the first scenario, 100 nodes are deployed in 100*m* × 100*m* network area, whereas, in the second scenario, 180 nodes are scattered in 180*m*× 180*m* network area. whereas, in the third scenario, 180 nodes are scattered in 210*m*× 210*m* The simulation parameters used are shown in Table .

|  |  |
| --- | --- |
| **Simulation Parameter** | **Value** |
| Simulator | MATLAB |
| Network size | 100x100, 180x180, 210x210 |
| nodes | 100, 180 |
| z | 0.05 |
| normal node energy | En=0.2 (joules) |
| advanced node energy | Ea=En\*(1+z) |
| super node energy | Es=En\*(1+2z) |
| energy per transmission | ETX=50\*10(-9) (joules) |
| energy for receiving | ERX=50\*10(-9) (joules) |
| energy for amplification | Eamp=100\*10(-12) (joules) |
| data aggregation energy | EDA=50\*10(-12) (joules) |
| packet size | k=2000 bits |

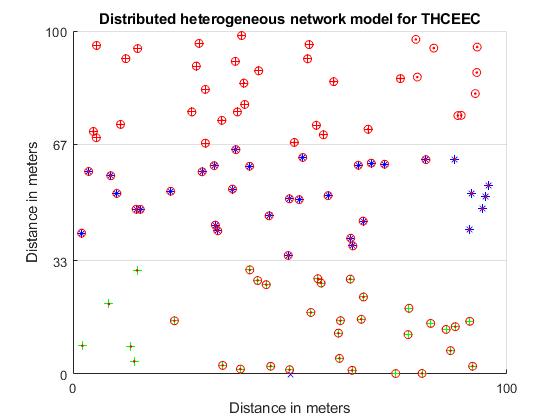
**Table: 6.1 Simulation Parameter table**

**6.1 Results for 100x100 area with100 nodes**

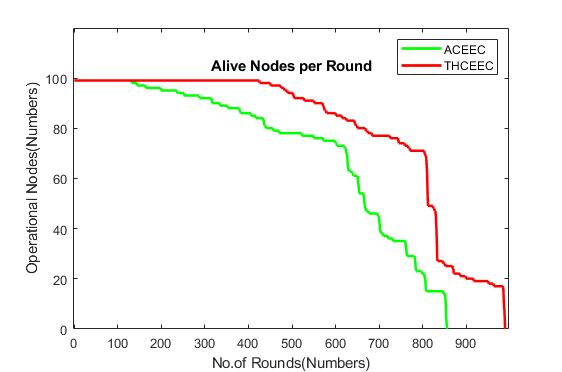
In the first scenario, a network area of 100*m* × 100*m* is divided into three regions Low Energy Region, Medium Energy Region and High Energy Region and 100 nodes are deployed randomly in the network. For THCEEC protocol and Base Station selects required number of Cluster Heads in each region. These three regions are again divided into 9 regions for ACEEC protocol as ACEEC protocol considers each of these sub divided regions as a cluster and in each cluster Base Station selects a cluster head. The BS is placed at the top of the network.



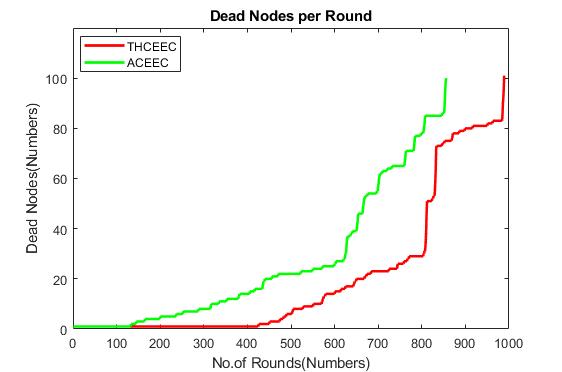
**Fig: 6.1 ACEEC network model**



**Fig: 6.2 THCEEC network model**



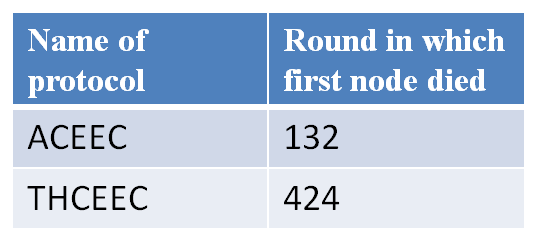
**Fig: 6.3 Plot of Number of Alive nodes vs Number of Rounds**



**Fig: 6.4 Plot of Number of Dead nodes vs Number of Rounds**

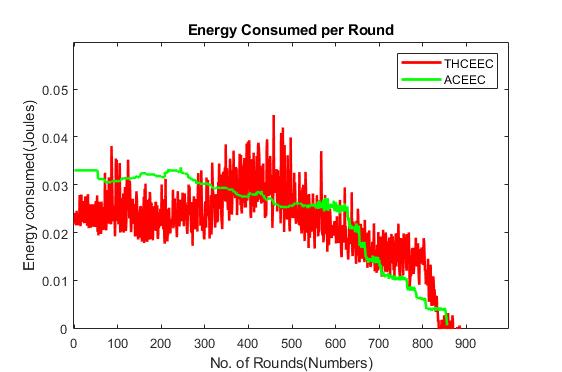
Above plots show the number of alive nodes, dead nodes with respect to operational iterative rounds. Performance results show that THCEEC has maximum network lifetime as compared ACEEC protocol.

**Fig: 6.5 Comparison of Network stability period**



**Table: 6.2 Comparison of Network stability period**

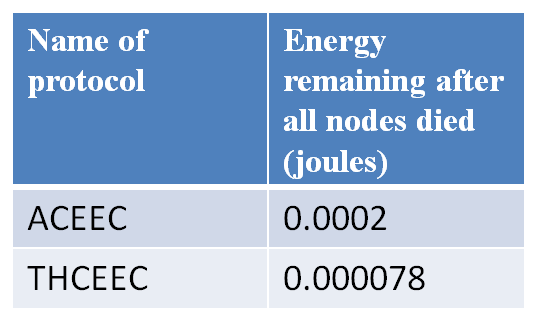
By comparing the network stability period we can see that THCEEC protocol offers most stability period than ACEEC protocol by 292 rounds.



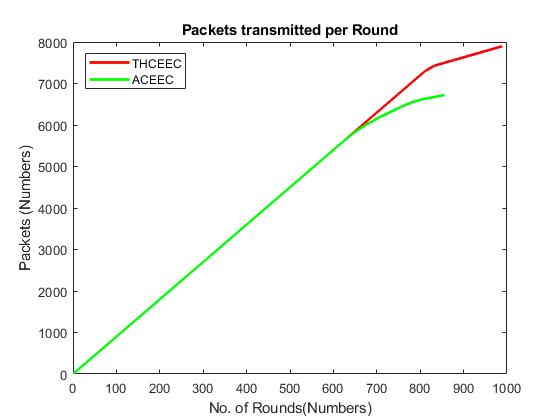
**Fig: 6.3 Plot of Energy Consumption vs Number of Rounds**

Above plots show the energy consumed with respect to rounds. Performance results show that THCEEC has less energy consumption even though it has fluctuations in energy consumption as compared ACEEC protocol.

**Fig: 6.5 Comparison of Average remaining energy in all nodes**



**Table: 6.5 Comparison of Average remaining energy in all nodes**

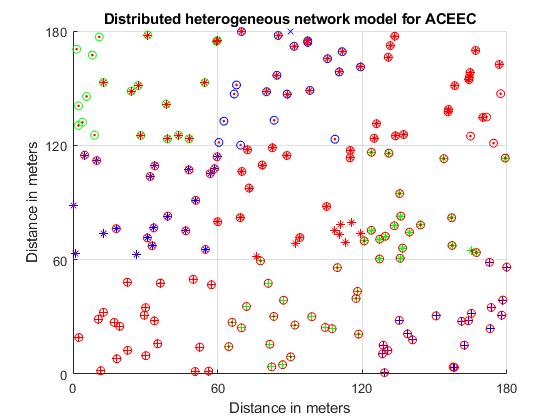


**Fig: 6.3 Plot of Number of Packets vs Number of Rounds**

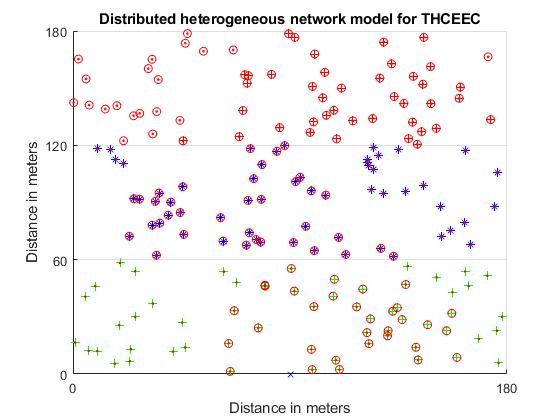
Above plot show us that the number of packets transmitted to the base station in THCEEC protocol is more than ACEEC protocol.

**6.2 Results for 180x180 area with180 nodes**

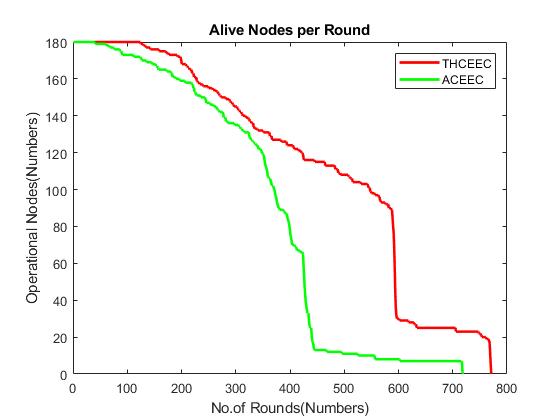
In the first scenario, a network area of 180*m* × 180*m* is divided into three regions Low Energy Region, Medium Energy Region and High Energy Region and 180 nodes are deployed randomly in the network. For THCEEC protocol and Base Station selects required number of Cluster Heads in each region. These three regions are again divided into 9 regions for ACEEC protocol as ACEEC protocol considers each of these sub divided regions as a cluster and in each cluster Base Station selects a cluster head. The BS is placed at the top of the network.

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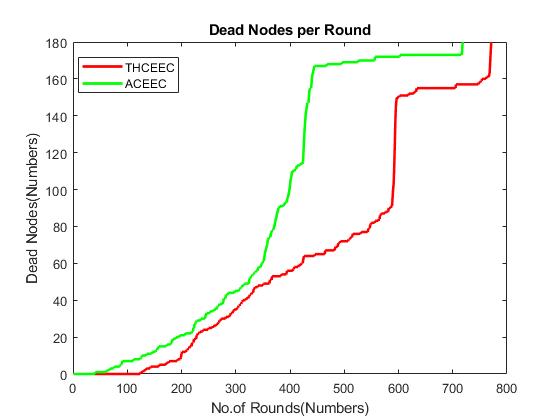
**Fig: 6.1 ACEEC network model**

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**Fig: 6.1 THCEEC network model**

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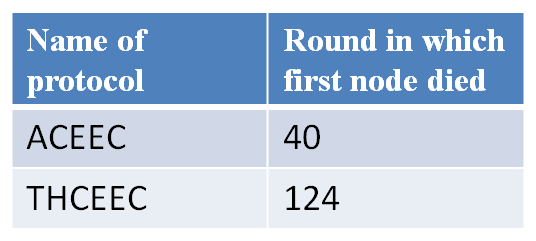
**Fig: 6.3 Plot of Number of Alive nodes vs Number of Rounds**

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**Fig: 6.3 Plot of Number of Dead nodes vs Number of Rounds**

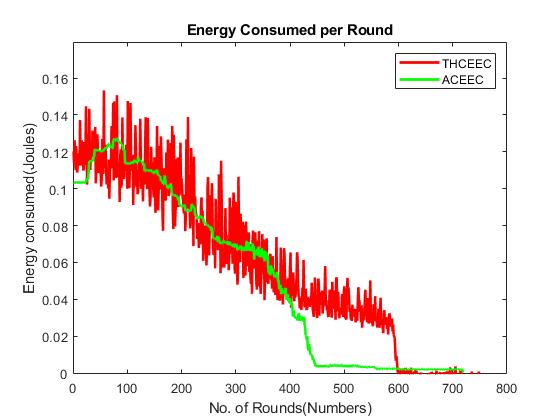
Above plots show the number of alive nodes, dead nodes with respect to operational iterative rounds. As the number of nodes deployed increases and network area increases THCEEC shows maximum network lifetime as compared ACEEC protocol.

**Fig: 6.5 Comparison of Network stability period**

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**Table: 6.5 Comparison of Network stability period**

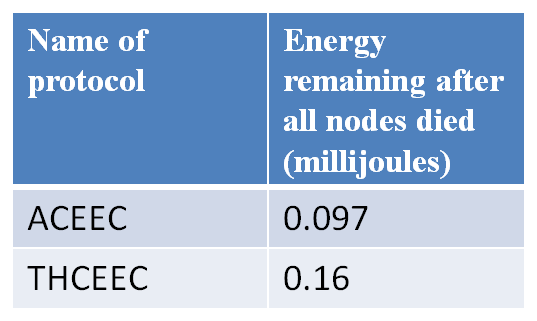
After increasing the network area and number of nodes the network stability period we can see that THCEEC protocol offers most stability period than ACEEC protocol by 84 rounds.

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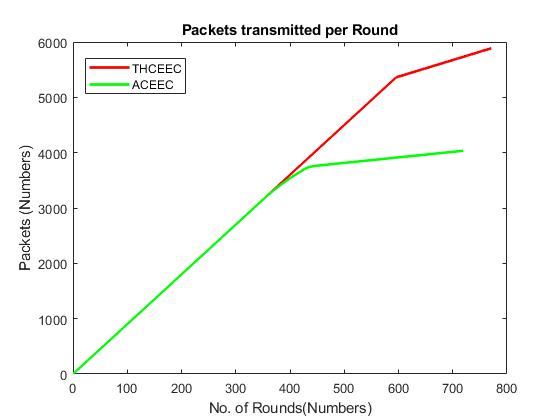
**Fig: 6.3 Plot of Energy Consumption vs Number of Rounds**

Above plots show the energy consumed with respect to rounds. Performance results show that THCEEC has less energy consumption even though it has fluctuations in energy consumption as compared ACEEC protocol.

**Fig: 6.5 Comparison of Average remaining energy in all nodes**

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**Table: 6.5 Comparison of Average remaining energy in all nodes**

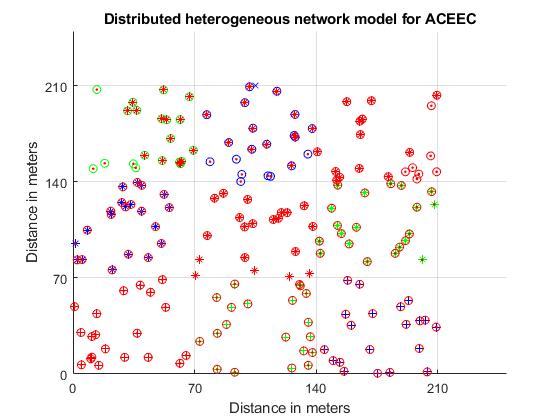
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**Fig: 6.3 Plot of Number of Packets vs Number of Rounds**

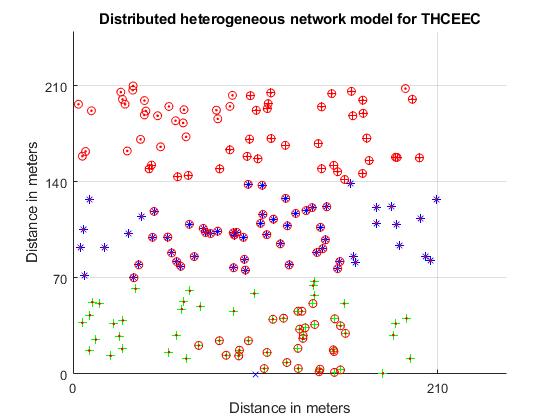
Above plot show us that the number of packets transmitted to the base station in THCEEC protocol is more than ACEEC protocol.

**Results for 210x210 area with180 nodes**

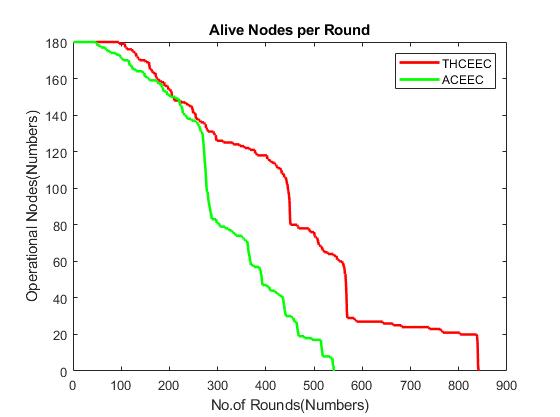
In the first scenario, a network area of 210*m* × 210*m* is divided into three regions Low Energy Region, Medium Energy Region and High Energy Region and 180 nodes are deployed randomly in the network. For THCEEC protocol and Base Station selects required number of Cluster Heads in each region. These three regions are again divided into 9 regions for ACEEC protocol as ACEEC protocol considers each of these sub divided regions as a cluster and in each cluster Base Station selects a cluster head. The BS is placed at the top of the network.

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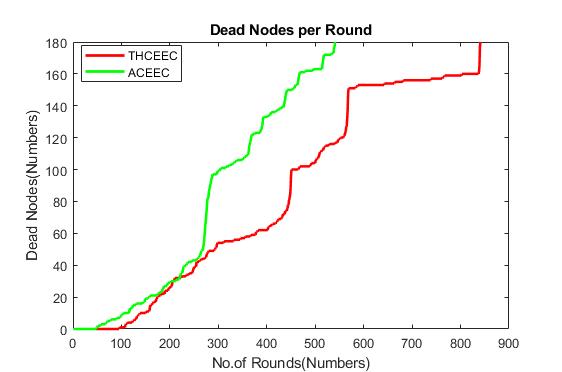
**Fig 6.1 ACEEC network model**

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**Fig 6.1 THCEEC network model**

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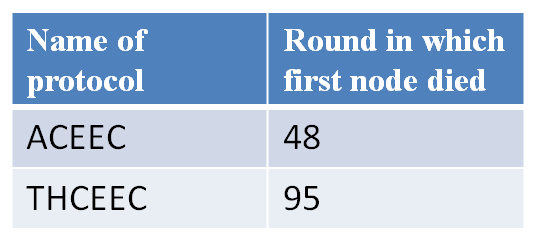
**Fig: 6.3 Plot of Number of Alive nodes vs Number of Rounds**

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**Fig: 6.3 Plot of Number of Dead nodes vs Number of Rounds**

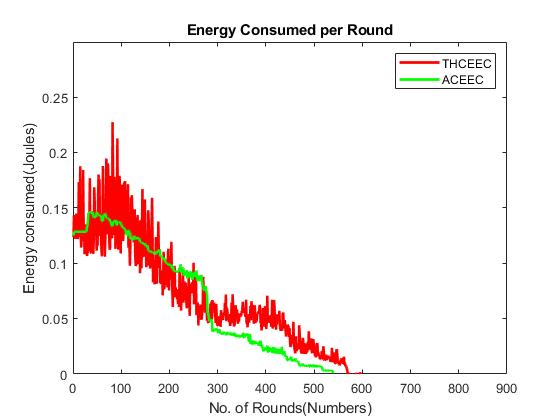
Above plots show the number of alive nodes, dead nodes with respect to operational iterative rounds. As the number of nodes deployed is constant and network area increases THCEEC shows maximum network lifetime as compared ACEEC protocol.

**Fig: 6.5 Comparison of Network stability period**

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**Table: 6.5 Comparison of Network stability period**

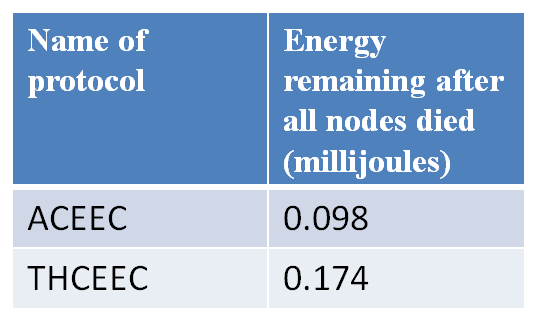
After increasing the network area network stability period we can see that THCEEC protocol offers most stability period than ACEEC protocol by 47 rounds.

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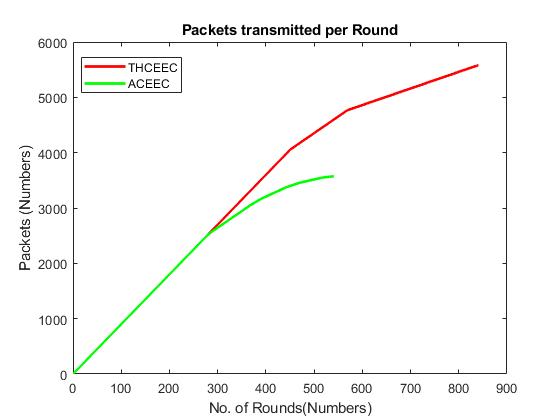
**Fig: 6.3 Plot Energy Consumption vs Number of Rounds**

Above plots show the energy consumed with respect to rounds. Performance results show that THCEEC has less energy consumption even though it has fluctuations in energy consumption as compared ACEEC protocol.

**Fig: 6.5 Comparison of Average remaining energy in all nodes**

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**Fig: 6.5 Comparison of Average remaining energy in all nodes**

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**Fig: 6.3 Plot of Number of Packets vs Number of Rounds**

Above plot show us that the number of packets transmitted to the base station in THCEEC protocol is more than ACEEC protocol.

# CHAPTER 7

## CONCLUSION

## REFERENCES