HIERARCHICAL ROUTING PROTOCOL
IN
WIRELESS SENSOR NETWORKS

A Dissertation submitted to the
School of Computer & Systems Sciences,
Jawaharlal Nehru University, New Delhi
In partial fulfillment of requirement for the award of the degree of

MASTER OF TECHNOLOGY
IN
COMPUTER SCIENCE AND TECHNOLOGY

BY
MEENAKSHI DIWAKAR

UNDER THE SUPERVISION OF
Mr. SUSHIL KUMAR

SCHOOL OF COMPUTER AND SYSTEMS SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI – 110067, INDIA

JULY 2009

DEDICATED

TO

My Parent and Siblings

जवाहरलाल नेहरु विश्वविद्यालय

SCHOOL OF COMPUTER AND SYSTEMS SCIENCES

JAWAHARLAL NEHRU UNIVERSITY

NEW DELHI – 110067, INDIA

CERTIFICATE

This is to certify that the dissertation entitled **"Hierarchical Routing Protocol in Wireless Sensor Networks"** being submitted by **Ms. MEENAKSHI DIWAKAR** to **School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi** in partial fulfillment of requirements for the award of the degree of **Master of Technology in Computer Science and Technology,** is a record of bonafide work carried out by her under the supervision of **Mr. Sushil Kumar**.

This work has not been submitted in part or full to any university or institution for the award of any degree or diploma.

Mr. Sushil Kumar 25/07/05

(Supervisor)

SC&SS, JNU,

New Delhi-110067

Dean

SC&SS, JNU,

New Delhi-110067

जवाहरलाल नेहरु विश्वविद्यालय

SCHOOL OF COMPUTER AND SYSTEMS SCIENCES

JAWAHARLAL NEHRU UNIVERSITY

NEW DELHI – 110067, INDIA

DECLARATION

This is to certify that the dissertation entitled **"Hierarchical Routing Protocol in Wireless Sensor Networks"** being submitted to the **School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi** in partial fulfillment of requirements for the award of the degree of **Master of Technology in Computer Science and Technology,** is a record of bonafide work carried out by me.

The matter embodied in the dissertation has not been submitted for the award of any degree or diploma in any university or institute.

MEENAKSHI DIWAKAR
M.Tech (2007-2009)
SC&SS, JNU,
New Delhi-110067

ACKNOWLEDGEMENT

My first thanks are to the Almighty God, without his blessings I couldn't complete this dissertation.

I would like to express my heartfelt thanks to my supervisor **Mr. Sushil Kumar**, for giving me the guidance, encouragement, counsel throughout my dissertation. Without his valuable advice and assistance, it would not have been possible for me to complete this dissertation.

I feel it is a great privilege to have had the opportunity to work under his prestigious supervision.

I thank all the Faculties in School of Computer and Systems Sciences who have always been helpful in any of the career perspectives.

I am thankful to **Dean** of the school and administration of JNU for providing a congenial environment for making our work a success. Their academic support has been a real asset in completing this work.

Thanks to my class mates, friends and all others for their discussions and help at all time during the course of my dissertation work.

Finally, my greatest gratitude and thanks to my parent, Vishal, Chhavi and Ruby, who have provided endless emotional support and unending encouragement.

None of this would be possible without their help and assistance and "thanks" is too little a word to express my feeling.

MEENAKSHI DIWAKAR

ABSTRACT

A Wireless Sensor Networks (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors and can be used for various applications areas like health, military, environmental etc. In many cases, the sensor nodes have limited power sources. So that utilizing sensor nodes' energy can maintain a prolonged network lifetime. One of the major issues in wireless sensor networks is developing an energy-efficient routing protocol which has a major impact on the overall lifetime of the sensor network.

In this dissertation, we proposed a protocol, EEHCRP (Energy-Efficient Hierarchical Clustering Routing Protocol), a protocol for wireless sensor network. In which, we divide the network into levels by using various power levels at base station and each level containing various sensor nodes. Each level is divided into clusters, whereby the packet is transmitted from a CH in the next level instead of direct to the BS.

The work presented in this dissertation is an outcome of simulations conducted using MATLAB. The results are obtained in terms of two metrics, lifetime of the network and energy consumption of clusters heads.

From the results of simulation, we observed that the performance of EEHCRP is better in terms of energy consumption of CHs and lifetime of network compared with LEACH.

CONTENTS

CHAPTER 2

Routing Techniques in WSN

CHAPTER 3

Related Work

CHAPTER 4

Proposed Work: EEHCRP (Energy Efficient Hierarchical Clustering Routing Protocol)

CHAPTER 5

Simulation Results

LIST OF FIGURES

CHAPTER-1

Chapter 1

Introduction to Wireless Sensor Network

1.1 Introduction:

Wireless sensor networks (WSN), these networks consist of individual nodes that are capable to interact with their environment by sensing or controlling physical parameters ; these nodes have to collaborate in order to fulfill their tasks as, usually, a single node is incapable of doing so; and they use wireless communication to enable this collaboration[1].

A sensor is a micro-electro-mechanical device. Each node of the sensor networks consists of four units [16].

1. The processing unit
2. The communication unit
3. The sensing unit
4. Power unit

Processing unit is normally related with an embedded operating system, a microcontroller to process data, and an internal memory to store data and application program. Processing unit manages the data acquisition, analyze the raw sensing data sensed by the sensor node, and generate the answer to the user requests. This unit also controls the communication and perform application specified task [15].

Communication unit, which is responsible for message exchange with neighboring sensor nodes [6]. In this subsystem, the transceiver connects the sensor nodes to the network [15].

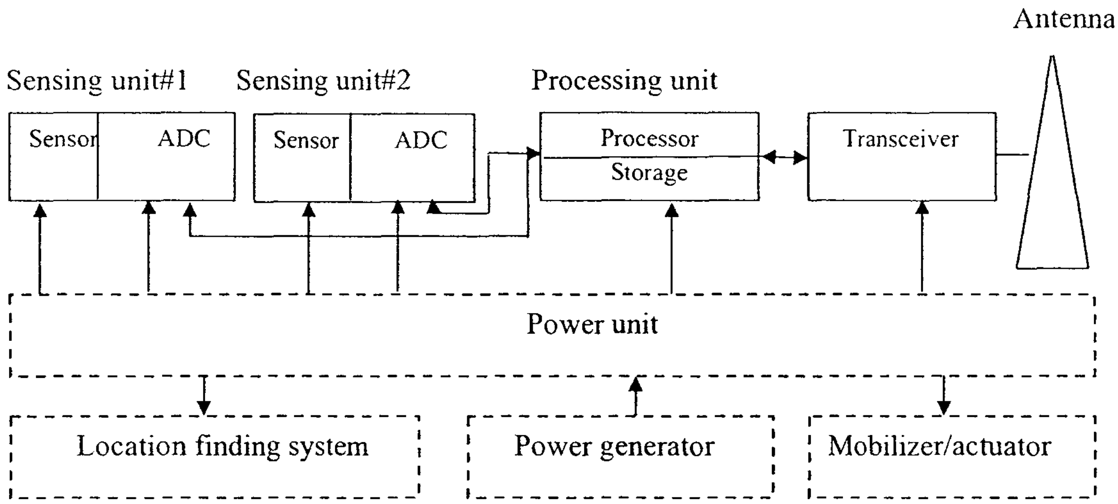

Fig 1.1 The components of sensor nodes [4]

The sensing unit is composed of a group of sensors and ADCs (analog to digital converter), which digitalize the analog signal produced by sensors when sensed a particular phenomenon. Depends on the type of output produce by the sensors, sensors can be as either analog or digital [16].

A power unit supplies the energy to all the working parts of the node and usually consists of a battery. A voltage regulator can be added to maintain the output voltage at a fixed value [16].

Additionally, a sensor node may have application dependent functional subsystem such as a location finder, a mobilizer, a power generator and other special-purpose sensors. The number of such subsystem may vary, depending on the application [15].

All the sensor nodes send or receive data to/from a fixed wired station called base station (BS). The base station usually serves as a gateway to some other network.

1.2 Architectures of Wireless Sensor Networks:

The architecture of WSN can be categorized in three categories.

1.2.1 Layered architecture:

The layered architecture has a single power full base station (BS), layers and the layer of nodes around it. The definition of a layer is a group of nodes that has the same hop-count to the base station. The base station acts as an access point to a larger network and can also be a data-gathering and processing entity.

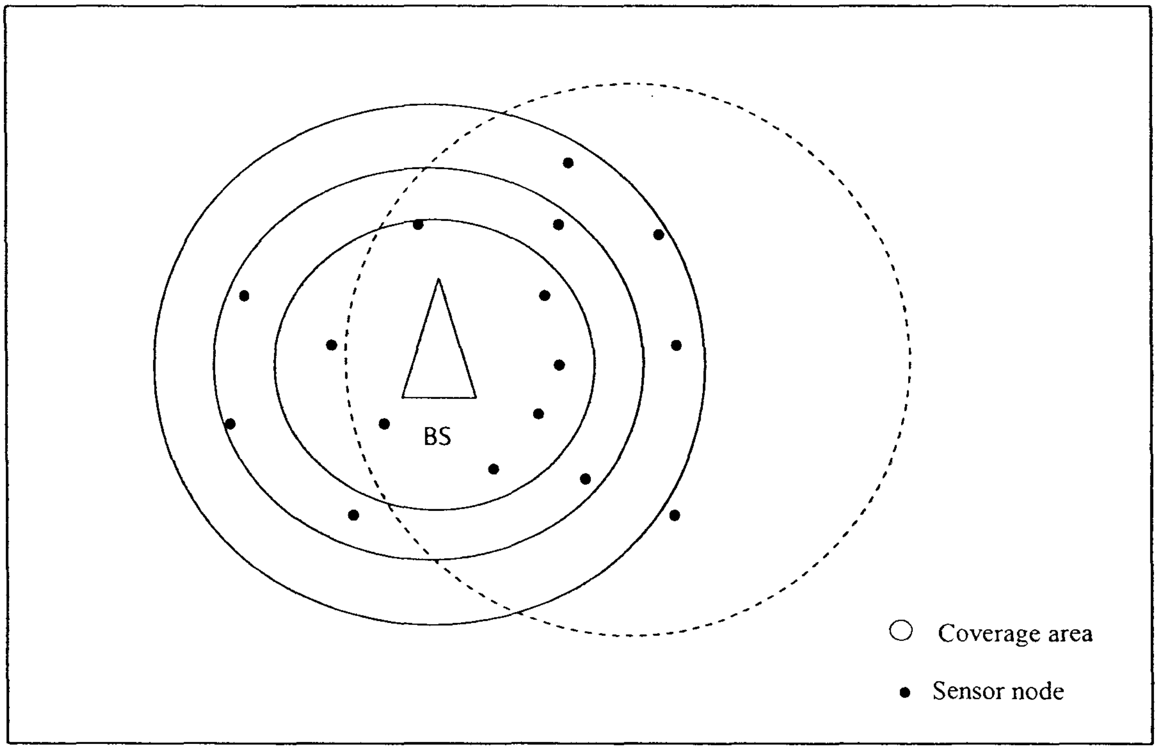

Fig1.2 Layered Architecture [5]

The advantage of a layered architecture is that each node is involved only in short-distance, low-power transmissions to nodes of the neighboring layers.

This architecture has been used with in building wireless backbones and in military sensor-based infrastructures [5].

1.2.2 Clustered Architecture:

A clustered architecture organizes the sensor nodes into clusters, each governed by a cluster-head. The nodes in each cluster is involved in message exchanges with their respective cluster-heads, and these heads send messages to a base station.fig [1.3] represents a clustered architecture, where any message can reach the BS in at most two hops. Cluster architecture is useful especially for sensor networks because it provide suitability for data fusion. Clustering can be extended to greater depths hierarchically [6].

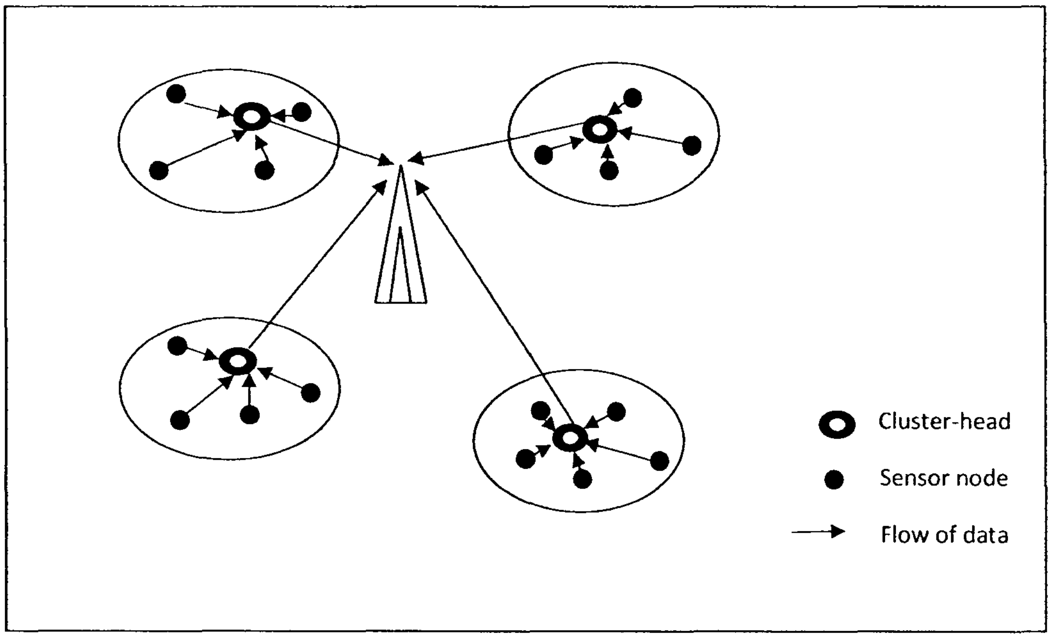

Fig1.3 Clustered Architecture [6]

1.2.3 Tired Architecture:

In this architecture, the sensor clusters perform the signâl processing of the observation and can include beam-forming, distribution detection/estimation, and data-fusion. The sensor clusters also perform data reduction, if necessary. The sensor network, which is one tire above of the sensor clusters, are responsible for transmitting data and performing domain level control message. The top level is the sensor application networks. The sensor application networks perform the routing and circulating the information to other enterprise entities for sharing information. The conceptual figure of tired-architecture is shown in fig [1.4] [5].

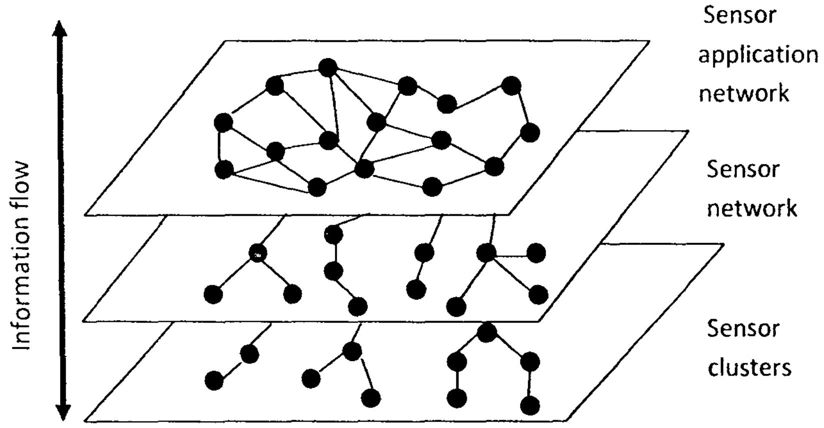

Fig1.4 Tired Architecture [5]

1.3 Challenges in Sensor Networks:

Sensor nodes communicate over wireless, lossy lines with no infrastructure. The main challenge is related to the limited, usually unrenewable energy supply of the sensor nodes. Hence, the available energy at the nodes should consider as a major constraint while designing protocols. Now we discuss the individual design challenge as follows [3, 4].

- **Power factors:**

The sensor node lifetime typically exhibits a strong dependency on battery life. In many cases, the wireless sensor node has a limited power source, and replacement of battery may be impossible. So that power management and power conservation are critical functions for sensor networks.

- **Hardware constraints:**

Hardware design for sensor nodes should also consider energy efficiency as a primary requirement. The micro controller, operating system, and application software should be designed to conserve power.

- **Node Unit Costs:**

A sensor network consists of a large number of sensor nodes. So the cost of an individual node is critical to the overall cost metric of the sensor networks. Therefore, the cost of each sensor node should be low.

- **Scalability:**

The sensor network should scale from ten to thousand of sensor nodes. In addition, the deployment density is also variable. This requires automatic-configuration, maintenance, upgrading of individual nodes.

- **Integrating With Real World:**

Real-time communication over sensor networks must be supported through provision of guarantees on maximum delay, minimum bandwidth, or other parameters.

- **Transmission Media:**

The wireless communication links operate, normally in the radio range. However some other sensor networks use optical or infrared communication. To facilitate worldwide operation of these networks, the transmission media selected must be available on a global basis.

- **Fault Tolerance:**

In sensor networks, nodes can fail due to problem of hardware, physical damage or depleting their energy supply. So the sensor network should be able of adapting to changing connectivity. This is relevant to the routing protocols that find the alternative path for rerouting the packet.

1.4 APPLICATIONS:

The application of WSNs can be categorized into four main categories.

1.4.1 Environmental Applications:

Some environmental applications of sensor networks include tracking the movements of birds, small animals, and insects, monitoring environmental conditions that affect crops and farm animals, irrigation, chemical/biological detection, precision agriculture; biological, forest fire detection, geophysical research, flood detection and pollution study [14].

1.4.2 Health Care:

WSN could potentially affect a number of health care applications such as medical treatment patient monitoring and people rescue [2].

- **Patient Monitoring:** In the patient monitoring, every patient could wear sensors, allowing doctors and nurses to continuously monitor their status and to react to changes.
- **Disability Assistance:** In this application, smart sensor operates within the human body to monitor important physiological parameter or particular organ viability.

1.4.3 Military Applications:

The military applications of sensor nodes include battlefield surveillance and monitoring, guidance systems of intelligent missile, and detection of attack by weapons of mass destruction, such as chemical, biological or nuclear and reconnaissance [6].

1.4.4 Home Applications:

In these applications, smart sensors nodes can be built in appliances, such as vacuum cleaners, micro-wave ovens, refrigerators, and VCRs. These sensor nodes inside the domestic devices can interact with each other and with the external network via the Internet or Satellite. They allow end users to manage home devices locally and remotely more easily. The home can provide a "smart environment" which adapt itself according to the user's choice [6, 14].

1.5 Motivation:

It is an attempt to analyze existing protocols LEACH, PEGASIS and some other protocols in their existing forms. Special emphasis is given to find out what is the scope of improvement that enhanced the lifetime of the WSN.

1.6 Problem Statement:

Energy awareness is an essential design issue for wireless sensor networks. When elects the cluster heads (CHs) in LEACH (Low Energy Adaptive Clustering Hierarchy), then there is no consideration about the distance of nodes from the BS and also CHs direct transmit data to the BS. So that unbalanced energy consumption occurs among the CHs.

1.7 Problem Definition:

In present work, we proposed EEHCRP (Energy Efficient Hierarchical Routing Protocol) based on different power levels for Wireless Sensor Networks. EEHCRP reduces the number of dead nodes and the energy consumption, to extend the network lifetime. We analyzed proposed protocol with the help of MATLAB and compared the performance of EECHRP with LEACH protocol in terms of:

- Lifetime of the network
- Energy consumption of CHs

1.8 Organization of Dissertation:

Chapter 1 gives a brief introduction about wireless sensor networks, architecture of WSNs, design challenges and applications of WSNs. This is followed by the problem statement and objectives to be met in this work.

Chapter 2 this chapter illustrates the challenges and design issues of routing, strategies and classification of routing in WSNs.

Chapter 3 includes the related work.

Chapter 4 in this chapter, propose a energy efficient hierarchical clustering routing protocol.

Chapter 5 Simulations and results of experiments are discussed in this chapter.

Chapter 6 Concludes the work presented in the dissertation and the scope of further extension of this work.

CHAPTER-2

Chapter- 2

Routing Techniques in WSN

Routing in sensor networks is very challenging due to several characteristics that differentiate them from contemporary communication and wireless ad hoc networks. First of all, it is more difficult to build a global addressing scheme for the deployment of sheer number of sensor nodes. Therefore, classical IP-based protocols cannot be applied to sensor networks. Second, in opposite to typical communication networks almost all applications of sensor networks want the flow of sensed data from multiple regions (sources) to a BS. Third, generated data traffic has considerable redundancy in it. Such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization. Fourth, sensor nodes are tightly constrained with energy and thus require careful resource management [18].

Now, we are going to discuss the routing mechanisms for sensor networks.

2.1 Data Dissemination and Gathering:

Data dissemination is the procedure by which data is routed in the sensor network. The sensor nodes collect the data and this data has to be communicated to the BS or to any other node. The node that creates data is known as Source. A node is called a Sink if it is interested in an event and obtains information about it [6].

The routes through which the data and queries are forwarded between the BS and sources are an important part and a basic feature of WSNs. A simple method to achieving this task is, for each sensor node sends directly to the Base Station.

A single-hop based approach is pricy as nodes that are farther away from the BS may exhaust their energy quickly, because of that limiting the life time of the network. To address the drawbacks of the single-hop approach, data interchange between the sensors and BS is normally accomplished using multi-hop data transmission over short communication path. This approach leads to saving significant amount of energy and reduces communication interface between sensor nodes competing to chancel access [4].

In a multihop WSN, intermediate nodes must take part in forwarding data packets between the source and destination. The principal task of the routing algorithm is finding out which set of intermediate nodes is to be selected to form a data sending path between source and destination [4].

Now we are going to discuss the primary routing challenges and design goals of routing in WSNs.

2.2 Routing Challenges and Design Issues in WSNs:

The design of routing protocol in WSN is affected by many challenging components. These components are as follows [9, 18].

- **Node Deployment:**

Node deployment in WSN is depend on the application and affects the performance of routing. The node deployment can be either deterministic or randomized. In deterministic situation, the nodes are placed in the deterministic manner and paths are predetermined through which data is routed. However, in the random deployment, the sensor nodes are placed randomly and creating an infrastructure in an ad-hoc manner.

If the resultant distribution of the nodes is not uniform, then clustering becomes essential to allow connectivity and make it possible energy-efficient network operation.

Due to energy and bandwidth limitation, the inter sensor communication has done generally with in short transmission range.

Therefore it is most probable that a route will consist of multiple paths.

- **Networks Dynamics:**

There are three main factors in a sensor network. These are sensor nodes, BS and monitored events. Most of the network architecture assumes that sensor nodes are fixed. However, in many applications, both the BS or sensor nodes can be mobile [7].

Routing messages from or to moving nodes is more challenging since route and topology stability become an important optimization issue in addition to energy, bandwidth etc.

Moreover, the phenomenon can be dynamic (e.g. target detection/ tracking application). Monitoring fixed events allows the network to work in a reactive mode. In most application, dynamic events require periodic reporting to the base station.

- **Data Reporting Model:**

Depending on the application, the data reporting can be categorized as time driven, event driven, query driven and hybrid [8].

In time driven method, each sensor node transmit the data of interest periodically. In event driven method, the sensor node respond immediately when an event occur. In query driven method, sensor nodes react to a query generated by BS or another in the network. In many applications, the network uses any combination of time driven, event driven and query driven. The routing protocol is extremely influenced by the data reporting model in terms of energy consumption and finding the route.

- **Node Capabilities:**

In many sensor networks, all sensor nodes were assumed to be homogeneous having equal capacity in terms of computation, communication and power.

- **Data Aggregation:**

When sensor nodes sense some event, they may generate significant redundant data. For reducing the number of transmission, it is necessary to aggregate similar packets from multiple nodes.

Data aggregation is the combination of data from different sources by using aggregation functions. Data aggregation has been used to accomplish energy efficiency and traffic optimization in a number of routing protocol. Signal processing method is also feasible for data aggregation. This method is called data fusion where a node has capability to producing a more precise output signal. The nodes accomplish this task by reducing noise and using some techniques like beam forming to combine the incoming signals.

- **Scalability:**

The number of sensor nodes in the network may be hundred or thousand or more. Any routing protocol must be capable to work with this vast number of sensor nodes.

2.3 Routing Strategies in Wireless Sensor Networks

Routing algorithm for WSNs can be classified according to the approach in which information is acquired and maintained. Also consider the approach in which this information is used to calculate paths based on the acquired information. Routing strategies can be classified into three categories, namely, proactive, reactive, and hybrid protocols [9].

2.3.1 Proactive Routing strategies:

This strategy also referred as table-driven routing protocol. In this strategy, all routes are computed before they are really needed. Each node of the network maintains the network topology information in the form of routing tables. Information of the routing normally flooded in the network. When sensor nodes are static, it is preferable to proactive strategy [6].

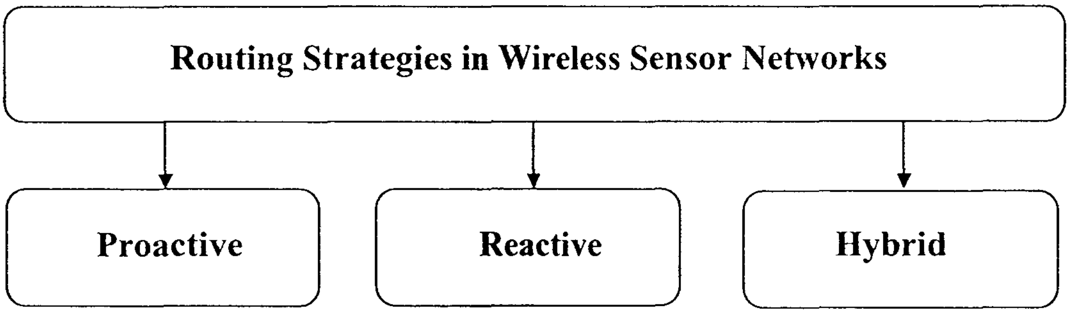

Fig 2.1 Routing strategies

2.3.2 Reactive Routing Strategies:

This strategy is also known as on-demand routing strategy. In this strategy, routes are computed on demands, by using a connection establishment process. These strategies do not maintain global information across all nodes of the network. Hence these strategies do not exchange routing information periodically and control flooding process to reduce significant amount of communication overhead [9].

2.3.3 Hybrid Routing Strategies:

Hybrid routing strategies combine the best features of the proactive routing strategies and reactive strategies. In these strategies the network is organized into mutually adjacent clusters. Nodes within a certain distance from the cluster concerned or within a cluster, are said to be within the routing resign of the given cluster. For routing within cluster, a proactive routing strategy is used. Reactive routing strategy is used across the clusters [6, 9].

2.4 Classification of Routing Protocols in WSNs

Routing protocols in WSNs are categorized according to its protocol operation and network structure. Depending on the network structure, protocols can be divided into flat-based routing protocol, hierarchical-based routing protocol, and location-based routing protocol. Furthermore, these protocols can be categorized into multipath-based routing, query-based routing, and negotiation-based, QoS-based routing, depending on the protocol operation.

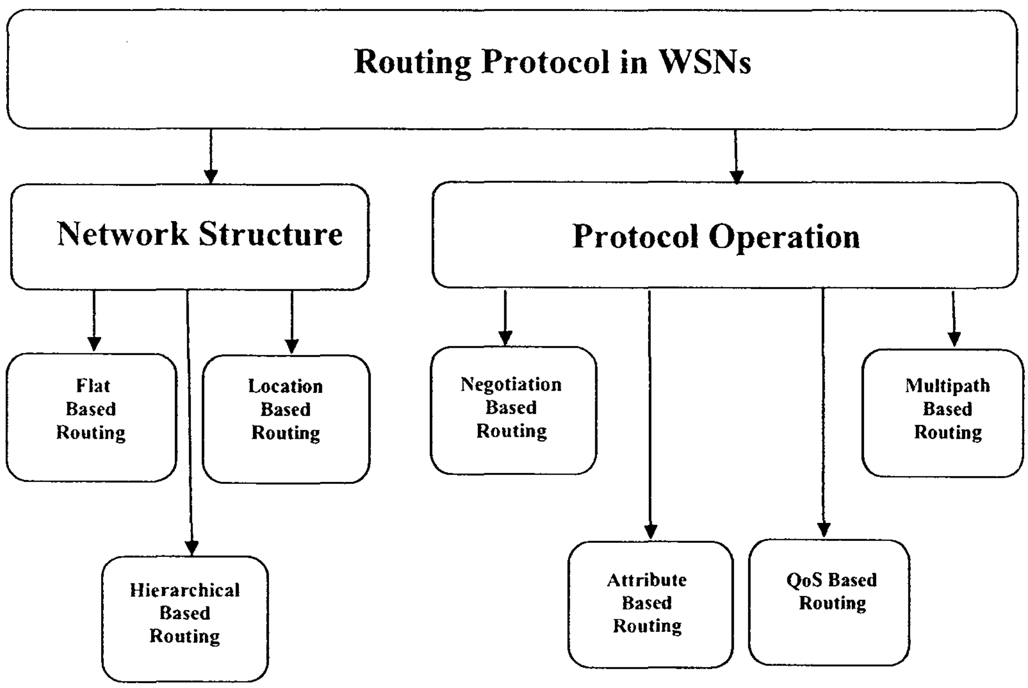

Fig 2.2 Classification of Routing Protocols in WSNs

2.4.1 Flat Routing Protocols:

In the flat network architecture, all nodes have assigned same roles. In most of the applications in the WSNs, it is not practicable to allot universal identifier due to greater number of sensor nodes deployment. This consideration has led to flat routing.

In the flat routing, BS sends queries to a selected area and waits for data from the nodes placed in that area. Since data is being requested through queries, attribute-based naming is compulsory to specify the properties of data.

A flat routing has several advantages, including save the energy and elimination of redundant data [9].

2.4.2 Hierarchical Based Routing Protocols:

This type of routing protocols also known as cluster based routing protocols. This type of protocols enforces a structure on the network to attain energy efficiency, extend the lifetime and scalability. In this protocol, nodes of the network are organized into the clusters in which higher energy nodes (e.g. assume the job of the cluster head)can be used to process and forwarding the information, while low energy nodes can be used to do the sensing the target. Clustering is an efficient way to reduce energy consumption and extend the life time of the network, doing data aggregation and fusion in order to reduce the number of transmitted messages to the BS [18].

2.4.3 Location Based Routing Protocols:

This type of routing protocols uses location to address a sensor node. The information of the location is required in order to compute the distance between the neighboring nodes so that energy consumption can be estimated. Location information of neighboring nodes can be obtained by message exchanging between the nodes of such information [10]. Also, the location of nodes can be obtained by GPS.

Location based routing is useful in most of the application where the location of the node within the environmental area of the network is relevant to the query issued by the source node. This query may specify a particular region or surrounding area of a particular point in the network environment [18].

2.4.4 Multipath routing Protocols:

This type of protocols use multiple paths instead of a single path (from source to sink) in order to improve the performance of the network. These protocols offer fault tolerance by having an alternative path between a source and a sink when the primary path fails. These alternative paths are kept alive by sending periodic messages. For this reason, energy consumption and traffic increase but also increase the reliability of the network [9].

2.4.5 Query- Based Routing:

In these protocols, the destination nodes circulate a query for data from a node through the network. The node containing this data that matches the query sends back to the node that initiate the query [9].

2.4.6 Negotiation-Based routing:

These types of protocols eliminate redundant data transmission through negotiation by using high-level data-descriptors.

The communication decisions are based on available resources and local interaction [9].

2.4.7 QoS-Based Routing:

In these protocols, the network has to balance between energy consumption and quality of data. In particular, the network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc. when sending data to the BS [9].

CHAPTER-3

Chapter-3

Related Work

In the second chapter, we discussed the routing challenges, design issues, routing techniques and routing protocols. However, this chapter presents only hierarchical based routing protocols.

3.1 LEACH Protocol:

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical routing protocol for sensor networks. LEACH is a cluster-based routing protocol which includes cluster formation in distributed manner. In LEACH [11], the nodes form themselves into local clusters, with one node acting as the local cluster-head. LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the several sensors nodes in order to not deplete the battery of a single sensor. In addition, CHs performs local data fusion to "compress" the amount of data arriving from the nodes that belong to the respective cluster and transmit aggregate data to the base station, further reducing energy dissipation and enhancing system lifetime.

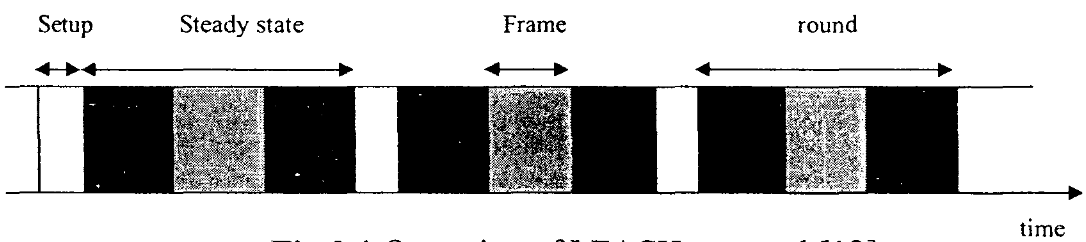

Fig 3.1 Operation of LEACH protocol [12]

LEACH uses a TDMA and CDMA Mac protocol for reducing inter-cluster and intra-cluster collisions. The operation of LEACH is divided in to two phase, the setup phase and steady state phase. In the setup phase, the clusters are formed and CHs are selected. In the steady state phase, data transfer to the BS. The time of steady state phase is usually longer than the time of setup phase for saving the protocol payload. Fig [3.1] shows the process.

- **Setup phase:**

Initially, when clusters are being created, each node determines whether or not to become a cluster-head for the current round. A predetermined fraction of nodes p elects themselves as CHs as follows.

A sensor node chooses a random number r, between 0 and 1. If this random number is less than a threshold valueT(n), the node becomes a cluster-head for the current round. The threshold value is calculated as.

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \left(\frac{1}{p}\right)\right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where p=the desired percentage of cluster heads.

r=the current round

G= the set of nodes that have not been cluster-heads in the last 1/p rounds.

All elected cluster-heads for the current round broadcasts an advertisement message to the rest of the nodes with the same transmit energy. For this "cluster-head-advertisement" phase, the cluster-heads use a CSMA MAC protocol. After this, each non-cluster-head node decides the cluster to which it will belong for current round. This decision is based on the received signal strength of the advertisement messages.

All non-cluster-head nodes must inform to the selected CHs that they will be a cluster member for the current round. Each node sends this information back to the cluster-head again using a CSMA MAC protocol.

The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

- **Steady State Phase:**

During the steady state phase, the sensor nodes can begin sensing and transmitting data to the CHs. Assuming nodes always have data to send. The radio of each non-cluster-head node can be turned off until the node's allocated transmission time, thus reducing energy dissipation in these nodes. After receiving all the data, the cluster head node performs signal processing functions to compress the data into a single signal and send to the BS.

After a certain time, which is determined a priori, the next round begins. To reduce interference between the clusters, each cluster communicates using different CDMA codes. Although LEACH is able to increase the life time of the network, but it has some issue about the assumption.

- **Drawbacks:**

In LEACH, each node can transmit directly to the cluster-head and the sink uses single-hop routing. Therefore, it is not applicable to networks deployed in large regions. Also, it is not obvious how the number of predetermined number of cluster heads is going to be uniformly distributed through the network. Therefore, it is possible no or lots of CHs selected and also possible that too many CHs are located in a specific area. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption. To solve this problem, an improvement version of LEACH was proposed, named LEACH-C [9].

3.2 LEACH-C Protocol:

This protocol is the extended version of LEACH protocol. It is the same as LEACH protocol except the setup phase.

In the setup phase, all nodes in the network transmit their information to the BS, includes their ID, remaining energy, and position information. After this, the BS calculate the average energy of the network and select a set of CHs that have more energy than the average energy of the network and sends information about CHs ,their members and TDMA schedule. The members nodes decide own TDMA slot and transmit data in its time slot [13].

- **Drawbacks:**

A non-sovereign cluster-head selection is the main drawback of this protocol. Moreover, LEACH-C needs location information of all nodes in the network. However, the location information in wireless sensor networks is only available through GPS (Global positioning system) or a location sensing technique, such as triangulation which requires additional communication among the nodes [20].

3.3 PEGASIS Protocol:

Power-efficient gathering in Sensor Information Systems (PEGASIS) is an enhancement of the LEACH protocol. PEGASIS forms chains from sensor nodes instead of multiple clusters and uses only one node in a chain to send data to the BS rather than multiple nodes. The chain is constructed in a greedy way. Each node only communicates with their closest neighbors along the communication chain. Gathered data moves from node to node, aggregated and finally transmit to the BS [14].

- **Drawbacks:**

Drawbacks of PEGASIS are as follows [19].

- Each sensor node is required to have additional local information about the wireless sensor network.
- When the PEGASIS protocol selects the head node, there is no consideration about the energy of nodes.
- When the PEGASIS protocol applies to the greedy algorithm for construct chain, some delay may occur.
- Since the head node is a single, it may happen to a bottleneck at the head node.
- When the PEGASIS protocol selects the head node, there is no consideration about the location of the base station.

CHAPTER-4

Chapter-4

Proposed Work

EEHCRP: Energy Efficient Hierarchical Clustering Routing Protocol

Hierarchical clustering algorithms are very important to increasing the lifetime of network. We propose EEHCRP (Energy Efficient Hierarchical Clustering Routing Protocol), which is a hierarchical clustering routing protocol. EEHCRP reduces the number of dead nodes and the energy consumption to extend the network lifetime. Before studying the details of the proposed algorithm, we define the expected network model and energy model.

4.1 Network Model:

Let us consider a sensor network, consisting of n sensor nodes, which is randomly deployed over in an area of wireless sensor network. We make some assumptions about the sensor nodes and the underlying network model:

- **Assumptions:**

1. There is one base station which is fixed and located at middle in a given sensor network
2. All sensor nodes are fixed and homogeneous with a limited stored energy.
3. Base station can transmit various power levels.
4. Each node senses the environment at a fixed rate and always has data to send to the base-station.
5. The nodes are equipped with power control capabilities to vary their transmitted power.
6. Nodes are not equipped with GPS unit.

4.2 EEHCRP Algorithm:

In this section, we describe our protocol in detail. This protocol is divided into three phases, setup phase, cluster setup phase and inter cluster routing phase.

- **Setup phase:**

On the initial deployment, the base station (BS) transmits a level-1 signal with minimum power level. All nodes, which hear this message, set their level as 1. After that, the base station increases its signal power to attain the next level and transmit a level-2 signal. All the nodes that receive the massage but do not set the previous level set their level as 2.

This procedure continuous until the base station transmits corresponding massages to all levels. The total number of messages of levels is equivalent to the number of distinct transmit signal at which the BS can sends [17].

BS broadcast a hello massage, fig [4.1]. This massage contains the information of upper limit and lower limit of each level.

Ui, Li	....	U3, L3	U2, L2	U1, L1

Fig 4.1 Structure of hello message

Where Ui: Upper limits of level i

Li: Lower limit of level i

Each node calculates the distance from the BS based on the received signal strength.

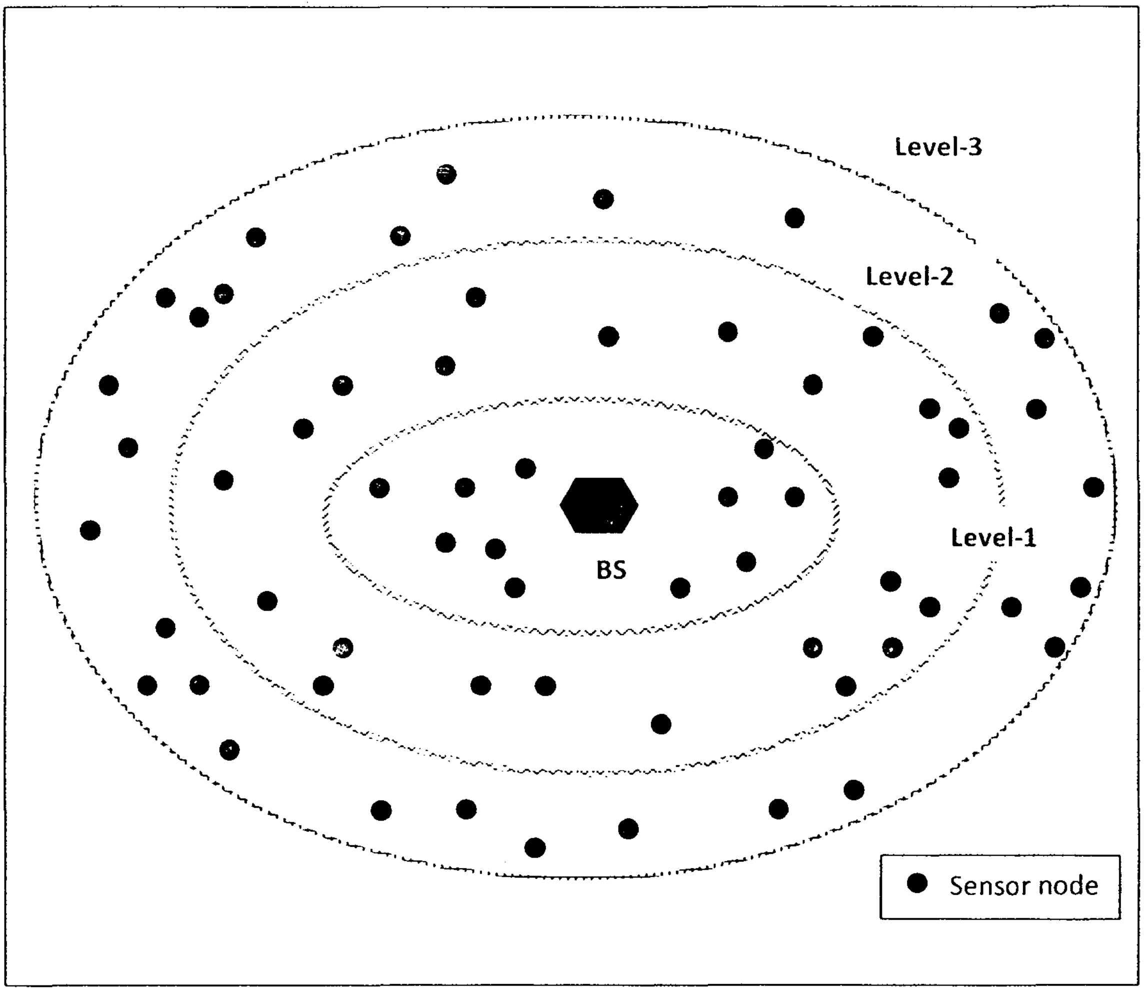

Fig4.2 Level assignment of network

- **Cluster setup phase:**

In this phase, each level is divided into clusters.

The operation of cluster-setup phase is the same as LEACH [11] except the difference of threshold formula.

For each level i, initially when clusters are being created, each node decides whether or not to become a cluster head for the current round. For this, node n chooses a random number x between 0 and 1. If this number is less than the threshold $T_i(n)$, the node become a cluster heads for the current round. The threshold is defined as:

$$T_i(n) = \begin{cases} \dfrac{P \times c}{1 - P \times (r \bmod \frac{1}{P})} \times \left(\dfrac{U_i - d(n, BS)}{U_i - L_i} \right) & \text{If } n \in Z \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

Where

P = the desired percentage of the cluster heads.

r = the current round.

Z = the set of nodes that have not been cluster-heads in the last 1/P rounds.

c = the constant between the 0 and 1.

U_i = the upper limit of level-i.

L_i = the lower limit of level i.

d (n, BS) =the distance between node n and base station.

Each node that elected itself a cluster head for the current round, broadcast an advertisement message to the rest of the node by using CSMA Mac protocol. All cluster heads broadcast their advertisement message with the same transmit energy.

All non- cluster head nodes receiving these messages from all cluster head nodes and each non-cluster node decided the cluster to which it will belong for the current round.

This decision is based on received signal strength of the advertisement messages. Each node must inform to the cluster head that it will be a cluster member by using CSMA Mac protocol.

After that, each cluster head creates a TDMA schedule for its cluster members. This information is broadcasted back to the nodes in the cluster.

Once the clusters are created and TDMA schedule is fixed, data transmission can begin. Each cluster member can be turned off until the node's allocated time.

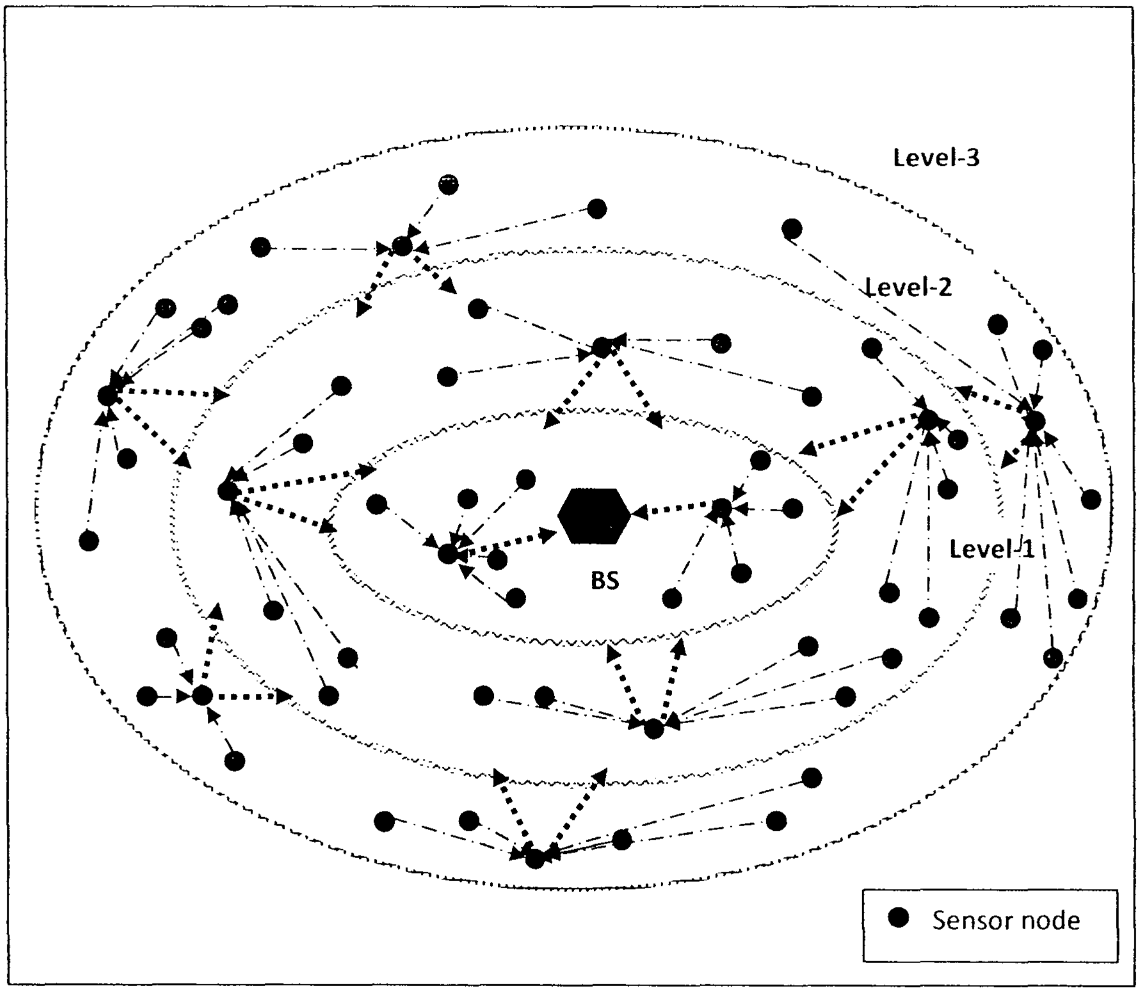

Fig 4.3 Cluster formation

Each node sends data to its cluster head with minimal transmission power. This power is estimated by received signal strength of the advertisement message. So that data transmission uses a minimal amount of energy.

When all the data has been received from the cluster members, then cluster head node perform data aggregation function to compress the data into a single signal. After a certain time the next round begin.

- **Inter cluster routing:**

After the cluster formation, the cluster heads broadcast the aggregate data to the next level. At the next level, the nodes aggregate their data and sends to their cluster heads.

In this manner the cluster heads at the last level transmit the final information to the BS.

4.3 Algorithm

- **Setup phase:**

No. of nodes N

BS can transmit i levels; $i \geq 1$

1. For each level i, message transmitted by BS
2. If (Nodes does not assign previous level and hear new message or BS transmit level i = 1)
3. Assign level i
4. End if
5. End for
6. BS broadcast hello message, which contains the information of upper limit and lower limit of each level.
7. Each node calculates the distance from the BS based on received signal strength.

- **Cluster setup phase:**

1. For each (node N)
2. N selects random number x between 0 and 1.
3. If (x< T (n))
4. N becomes CH.
5. N broadcasts an advertising message for its CH status.
6. Else
7. N becomes a NCH node.
8. N chooses the CH, this selection is based on the received signal strength of advertise.
9. N informs the selected CH and become a member of its cluster.
10. End if.
11. For each (CH)
12. CH creates TDMA schedule for each cluster member.
13. Each cluster member communicates to the CH in its time slot.

14. End for

- **Inter cluster routing:**

1. For each (level i)
2. For each CH
3. CH receives the data from the cluster member
4. Aggregate the data.
5. If (i ==1)
6. CH transmits data to the BS.
7. Else
8. CH broadcasts data in the next level.
9. End if
10. End for
11. End for

is there any difference between transmitting to BS and broadcasting to the next level?

4.4 Energy Model:

We use a free space model. This model is used to calculate the power of received signal of each packet. The free space propagation assumes the perfect propagation condition that there is only one clear line-of-sight path between the transmitter and receiver.

The energy consumed during the transmission is the main part of the total energy consumption.

The following equation is used to calculate the received signal power in free space at a distance r from the transmitter [21].

$$p_r dBm = p_t dBm + 10\log_{10}(G_l) + 20\log_{10}(\lambda) - 20\log_{10}(4\pi) - 20\log_{10}(r) \quad \dots\dots(1)$$

Where p_t is the transmitted signal power, G_l is the product of transmit and receive antenna field radiation patterns in the line-of-sight (LOS) direction and λ is the carrier wavelength.

The minimum transmission power level p_{t_min} at the sender is calculated as.

$$p_{t\_min}dBm = p_{r\_min}dBm - 10\log_{10}(G_l) - 20\log_{10}(\lambda) + 20\log_{10}(4\pi) + 20\log_{10}(r) \quad \ldots\ldots.(2)$$

From (1) and (2), we obtain.

$$p_{t\_min}dBm = p_{r\_min}dBm - p_r dBm + p_t dBm \quad \ldots\ldots\ldots.(3)$$

Where p_{r_min} is the receiver's sensitivity.

The non cluster head nodes calculate the strength of the advertisement messages from equation (1) and join the cluster which has the maximum strength of the received signal. These nodes also calculate the minimum transmission power for sending data to the cluster head with the help of (3).

In free space model, to transmit a 1 bit message over the distance r, transmission energy consumption $E_{T(x)}(l,r)$ [11] is-

$$E_{T(x)}(l,r) = E_{T(x-elec)}(r) + E_{T(x)-amp}(l,r) \quad \ldots\ldots(3)$$

$$E_{T_{(x)}}(l,r) = E_{elec} * l + \varepsilon_{amp} * l * r^2 \quad \ldots\ldots.(4)$$

Where $E_{T(x)-elec}$ is the energy dissipated by the transmitter electronics and ε_{amp} is the energy dissipated by the transmit amplifier.

$$E_{R_x}(r) = E_{R_{x-elec}}(r) \quad \ldots\ldots(5)$$

$$E_{R_x} = E_{elec} * r \qquad \ldots\ldots.(6)$$

Where $E_{R_{(x)-elec}}$ denote the receiver electronics.

CHAPTER-5

Chapter -5

Simulation results

In this section, we evaluate the performance of our proposed algorithm via MATLAB (with 5% of being cluster heads) and compare with LEACH protocol, which is a cluster based hierarchical routing protocol.

We simulated the energy consumption and resulting lifetime of the network. The results obtain in terms of two metric, energy consumption of CHs and life time of WSN are represented in form of graphs.

We assume that 100 sensor nodes are randomly deployed over 100 x 100 m square area sensor field and the whole network is divided in three levels (n=3). The BS located at (50, 50). The initial energy of each node is .05 J and a node is considered dead when its energy is less than equal to 0.

Table [1], shows the simulation parameters.

Parameter	**Value**
Network size	100 × 100 m
BS location	(50, 50)
Number of sensor nodes	100
Initial energy	.05 J
E_{elec}	50nJ/b
ε_{mp}	10 pJ/b/m^2
EDA	5 nJ/b/signal
Data packet size	4000 bits
n (level)	3

Table [1]

5.1 Energy consumption of cluster heads (CHs):

We compare the amount of energy consumed by CHs in our proposed algorithm EEHCRP and LEACH protocol for 30 rounds (fig 5.1).The energy consumed by CHs for each round in EEHCRP is much lower than that in LEACH.

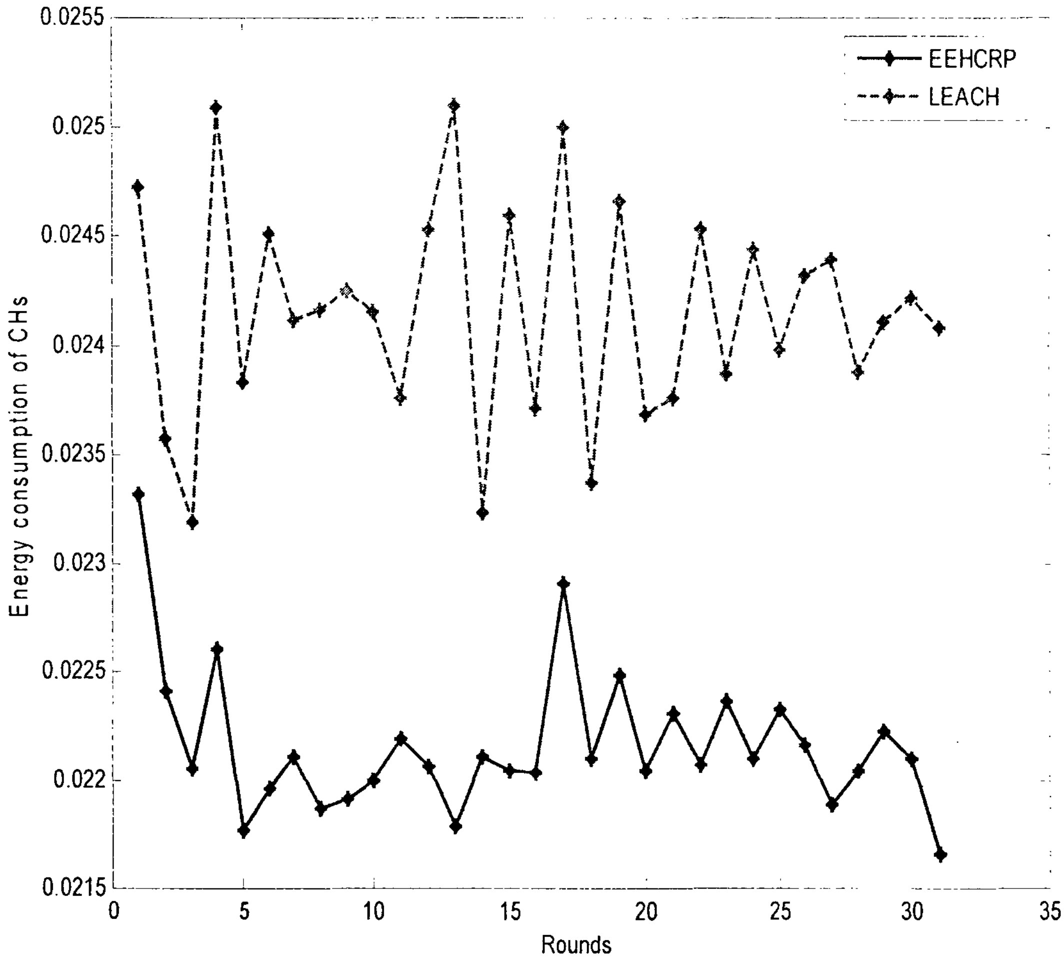

Fig 5.1 The amount of energy consumed by CHs using EEHCRP and LEACH

In LEACH, CHs transmit their data direct to the BS. Therefore, the energy consumption is much higher. In EEHCRP, CHs sends their data to the BS through multihop communication. So a considerable amount of energy is saved.

5.2 Life time of WSN:

We compare the energy efficiency of two protocols by measuring of time until the first node dies and time until the last node dies for 250 rounds. Fig 5.2 shows the simulation results between the number of rounds and alive nodes.

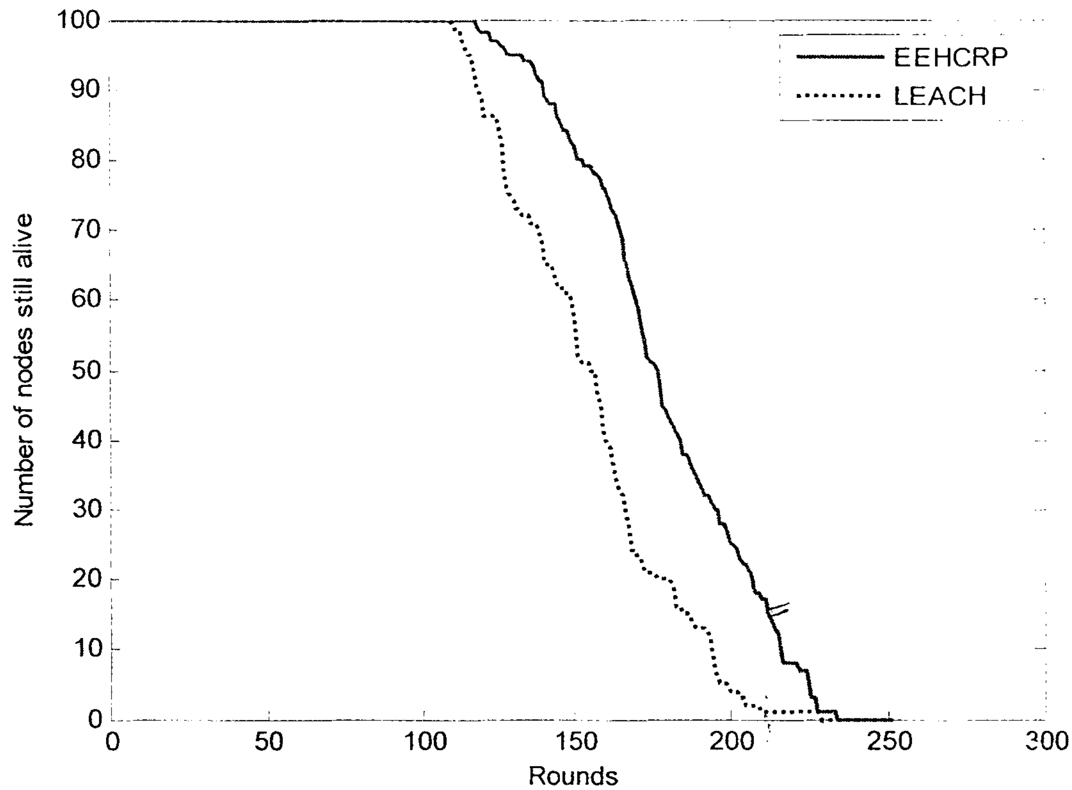

Fig 5.2 Network lifetime using EEHCRP and LEACH with .05 J/node.

The first dead node appeared in 117 rounds for EEHCRP, in 109 rounds for LEACH and the last dead node appeared in 233 rounds for EEHCRP, in 228 rounds for LEACH. Simulation results shows that our algorithm can extend the network life time approximately 4% against LEACH before the first node dies and approximately 3% before the last node dies. It is shows that the proposed algorithm EEHCRP improves the life time of network than the LEACH protocol.

At least how many nodes are required to hold the network functioning? Since one node live has no meaning?

CHAPTER-6

Chapter 6

Conclusion and Future Work

Wireless sensor networks are used in many applications. To save the energy is one of the most important issues in WSN. Energy efficient routing is paramount to increase the lifetime of the WSNs.

In this dissertation, we have proposed a Hierarchical clustering based Routing using leveling scheme. In this scheme, the network is divided into levels and each level is divided into clusters. The leveling is decided by the BS. In cluster head election phase, consider the distance from the BS to each node and also from the levels, in which node belongs.

In intra cluster communication, the cluster member sends data to the cluster head with minimum power. The CHs sends the aggregate data to the next level instead of direct to BS. So that save the energy of CHs and extend the life time of the network.

Simulation results shows EEHCRP extends the lifetime of WSN approximately 4% compared with LEACH before the first node dies and approximately 3% before the last node dies and energy consumption by cluster heads in EEHCRP is much lower than that in LEACH.

In future research, we will study to optimize the number of levels to efficiently consume the energy of all nodes and improve the network lifetime. We also want to extend our algorithm to heterogeneous WSNs.

REFRENCES

References

[1] Holger Karl and Andreas Willig. "Protocols and Architecture for Wireless sensor networks," Wiley, 2005.ISBN:0470095105.

[2] A.-B. Garcı´a-Hernando et al., "Problem Solving for Wireless Sensor Networks".

[3] Ankit Mehta, Deepak T.J, Arpit Mehta. Compendium of Applications for wireless sensor Networks.

[4] Kazem Sohraby, Daniel Minoli, Taieb Znati. Wireless Sensor Networks-Technology, protocol, and Applications.

[5] William Y. Chang, "Network-Centric Service-Oriented Enterprise," Springer Netherlends: 157-209.

[6] C.Siva Ram Murthy and B.S.Manoj. Ad-hoc wireless networks (Architecture and protocols).

[7] F. Ye, H. Luo, J. Cheng, S. Lu, L. Zhang, "A Two-tier data dissemination model for large-scale wireless sensor networks", proceedings of ACM/IEEE MOBICOM, 2002.

[8] Y. Yao and J. Gehrke, "The cougar approach to in-network query processing in sensor networks", in SIGMOD Record, September 2002.

[9] Jamal N. Al-Karaki Ahmed E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey," IEEE Wireless Comunication, Dec.2004.

[10] S. Capkun, M. Hamdi, J. Hubaux,"GPS-free positioning in mobile ad-hoc networks", Proceedings of the 34th Annual Hawaii International Conference on System Sciences, 2001 pp. 3481-3490.

[11] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan, "Energy-Efficient Communication Protocol forWireless Microsensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences – 2000

[12] Fan Xiangning. Song Yulin, "Improvement on LEACH Protocol of Wireless Sensor Network", 2007 International Conference on Sensor Technologies and Applications.

[13] Heinzelman W, Candrakasan A, Balakrisnan H. "AN Application-Specific Protocol Architecture for Wireless Microsensor Networks [J]", IEEE Transaction on Wireless Networking, 2000, 1(4): 660-670.

[14] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey".

[15] Li Cui, Fei Wang, Haiyong Luo, Hailing Ju, and Tianpu Li, "A Pervasive Sensor Node Architecture," IFIP International Federation for Information Processing 2004.

[16] Marcos A.M. Vieira, Adriano B. da Cunha, and Di´ogenes C. da Silva Jr, "Designing Wireless Sensor Nodes," Springer-Verlag Berlin Heidelberg 2006, pp. 99–108, 2006

[17] Dr.Garimella Rama murthy, Vasanth Iyer ,V.Bhawani Radhika, "Level Controlled Clustering In Wireless Sensor Networks," 2008 IEEE.

[18] Kemal Akkaya , Mohamed Younis, "A survey on routing protocols for wireless sensor networks," 2003 Elsevier B.V.

[19] Sung-Min Jung, Young-Ju Han, Tai-Myoung Chung,"The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS".

[20] SHANG Fengjun, "A Distributed Clustering Algorithm for Wireless Sensor Networks," Wuhan University Journal of Natural Sciences 2008, Vol.13 No.4, 385-390.

[21] Andrea Goldsmith, "Wireless Communications," Cambridge University Press, 2005, pp. 31-32.