Energy Efficient Clustering for Multihop Wireless Sensor Network

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DEDICATION

I dedicate my thesis to my Parents who has been a source of encouragement and motivation to me all the way through my life

A Dissertation submitted to

Department of Computer Science & Software Engineering,

Faculty of Basic and Applied Sciences,

International Islamic University, Islamabad

As a partial Fulfillment of Requirements for the Award of the

Degree of

MS in Computer Science

DECLARATION

I hereby declare that this thesis **"Energy Efficient Clustering for Multihop Wireless Sensor Network** "neither as a whole nor as a part has been copied out from any source. It is further declared that I have done this research with the accompanied report entirely on the basis of my personal efforts, under the proficient guidance of my teachers and my friends especially my supervisor Dr. Muhammad Zubair and Mr. Aftab Ali from NUCES FAST Islamabad. If any of the system is proved to be copied out of any source or found to be reproduction of any project from any of the training or educational institutions, I shall stand by the consequences.

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All praises to Almighty ALLAH, the most Gracious and Beneficial, Whose abundant blessings enable me to learn and recognize developed principles of life and make me able to reach at this point of success, requiem and peace for His beloved Prophet MUHAMMAD (May Peace and Blessings be upon Him) Who showed the righteous path to whole mankind and drag it out from the worst depths of ignorance to the outstanding level of humanity.

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I would also like thank to all of my friends for their support through my life and also during the course of this research work. Without their support this work cannot be completed.

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Project in Brief

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ABSTRACT

Wireless sensor Network (WSN) is an emerging area in the field of wireless networks. A WSN consists of thousands of tiny battery operated nodes. These nodes are generally provided with limitations of energy consumption during communication and improper charging due to typical structural conformations of WSNs. Hence the energy consumption in nodes is a serious dilemma in wireless sensor networks. Like other fields in networks the WSNs is experiencing numerous challenges in admiration to energy, routing and security. A number of researchers have particularly addressed on the energy consumption issue. It has been estimated that approximately 80% of energy is consumed for the duration in direct communication of sensor nodes to base station. In an attempt to address this concern the cluster based routing schemes have been introduced.

The clustering is a way to assemble data from group of similar or different items. A significant majority of cluster based schemes involve cluster head to cluster head type of multihop communications. However this type of communication may not be true in case of typical application scenarios headed for battery power. In this thesis we propose an efficient clustering scheme for multiop communication by the incorporation of gateway nodes. Our research work provides an optimal solution for the above stated problems. The simulation results prove that our scheme is exceedingly energy efficient for cluster heads and sensor nodes. Additionally the proposed technique has proved to enhance the network life time.

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LIST OF ABBREVIATIONS

Abbreviations	Explanation
BS:	Base Station
CH:	Cluster Head
CBRP	Cluster Based Routing Protocol
CH-CH	Cluster Head To Cluster Head
DCA	Distributed Clustering Algorithm
DMAC	Distributed and Mobility-Adaptive Clustering Algorithm
DEEC	Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks
EEHC	Energy efficient heterogeneous clustered scheme for wireless Sensor networks
EAP	Energy-Aware Routing Protocol in Wireless sensor Networks
EHRP	Energy-aware Hierarchical Routing Protocol in Wireless Sensor Network
EMHR	Energy- Efficient Multi-hop Hierarchical Routing Protocol for Wireless Sensor Networks
HWSN	Heterogeneous wireless sensor network
LEACH	Low energy adoptive Hierarchical Algorithm
SEP	Stable election protocol for clustered heterogeneous wireless sensor networks
SDEEC	Stochastic Distributed Energy-Efficient Clustering
SFRP	Selective Flooding-based Routing Protocol for Clustered Wireless

	Sensor Networks
TBRP	Tree Based routing protocol in wireless Sensor network
TDMA	Time Division on Multiple Access
UCR	Unequal Cluster Based Routing For wireless sensor Network
VLEACH	Improvement on LEACH Protocol of Wireless sensor Network
ZREECR	Zone-Based Residual Energy and Energy Consumption Rate

1

INTRODUCTION

1. INTRODUCTION

The wireless sensor networks (WSN) is an expanding technology in ADHOC networks especially used to monitor the environmental and other related matters. In course of attractiveness and wide esteem of wireless sensor networks, this has developed as a hot research topic these days. The WSN consists of a large number of tiny nodes provided with smaller in size.

1.1 Wireless Sensor Network

The WSN consists of tiny wireless devices distributed elsewhere in the environment encompassed with sensors. A collaboration of these nodes is referred to as wireless sensor network [1]. This collaboration of nodes performs a multiple of tasks including sensing, alerting and tracking. Primarily the sensor nodes were employed only for military purposes, yet these have found successful usage in monitoring the natural phenomena and environmental alterations etc as well. However the sensor nodes cannot operate up to a larger distance as a result of limited energy. In an attempt to save the energy in nodes, a number of multihop schemes have been introduced.

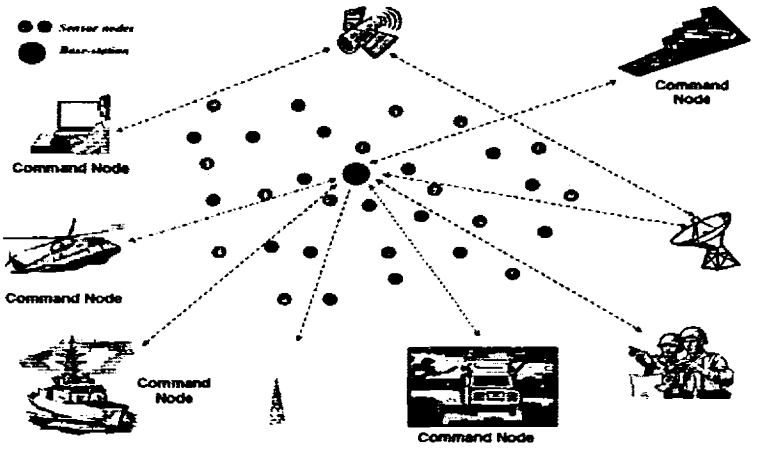

Figure 1-1: An articulation of sample WSN architecture for military application [1]

Some of the common applications of WSN are [2]

- Physical security for military operations
- Indoor/outdoor environmental monitoring
- Seismic and structural monitoring

- Industrial automation
- Bio-medical applications
- Health and wellness monitoring
- Future consumer applications, including smart homes.

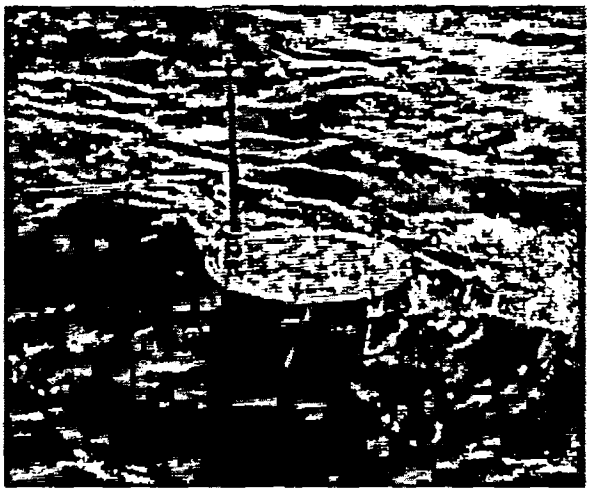

Figure 1-2: A sensor node for monitoring sea [6]

Some important properties of a sensor network are as follows [5].

A. Ease of deployment

The sensors can be deployed for monitoring of dangerous areas including landmines and sea etc that allows its users to extract information in a feasible manner which is not practicable in a normal way.

B. System Life Time

Sensor nodes are mainly battery operated and it is not practicable to either recharge or replace the battery when being deployed in hard areas. During their communication the energy in nodes is reduced. It is thereby very essential to design an energy efficient scheme that utilizes low energy.

C. Latency

Time plays a very important role in wireless sensor network. Data gathering in sensor network is typically time sensitive. Hence time sensitivity must be kept in mind while getting back data from sensor network.

D. Quality

Headed for quality, the wireless sensor network is diverse compared to other networks. In wireless sensor network the user is not interested in order to get all data back from the network. This is because the neighboring nodes have highly associated data that makes duplicate copy of this data over network. Secondly the user is only interested in user level events.

1.2 Components of Sensor Node

In technical terms the sensor node is known as mote. It consists of sensor node consists of basic four components as shown in Figure 2. These are Sensing unit, a processing unit, a transceiver unit and power unit. [3]

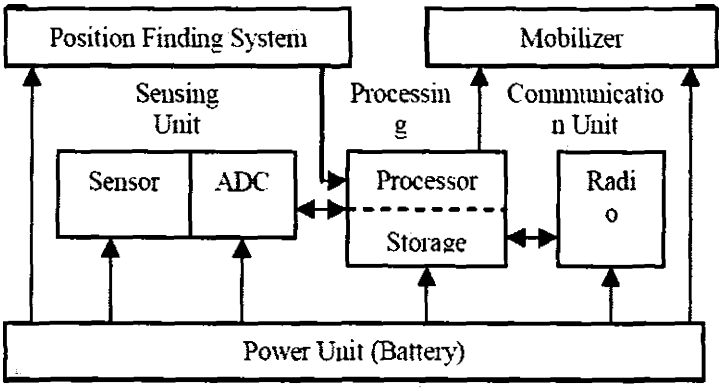

Figure 1-3: [8] Components of sensor Node

In this scenario user can get back information of his interest by via query. The results can be obtained by base station [8]. This works as an interface between user and sensor network.

The further division of each component of network is as follows.

1.2.1) Sensing Unit

Sensing unit is divided into two subunits. Sensor and analog to digital converter (ADCs).The sensor node work on analog signal is based on actual phenomena. This signal is converted to digital signal by using ADC. After the completion this signal is forward to processing unit.

1.2.2) Processing Unit

The processing unit is a small storage space piece responsible of monitoring all activities performed by a sensor node. The sensor node communicates with other sensing nodes and performs sensing tasks.

1.2.3) Transceiver unit

The transceiver unit connects the node to the network. This unit is used to send and receive the signals. Radio frequency (RF) is mostly used for wireless communication in this unit. Bluetooth is not preferably used due to their limited spectrum and scope in this unit for communication purposes.

1.2.4) Power unit

This is very important unit in the sensor network also referred to as heart of a sensor node. This is used to determine the life time of a sensor node. There are many possible sources of energies for this unit like solar cell and batteries etc, yet mostly commonly employed source of power is solar energy, which charges itself by using solar power.

1.2.5) Mobilizer

Mobilizer mainly facilitates the movement of sensor nodes from one location to another location.

1.3 Key Design Issues in WSN

WSN has some vital design issues that need attention of the researchers to make this technology more efficient. Important challenges for design of this network involve the communication bandwidth and energy [5]. These key design issues in WSN include the development of energy efficient schemes, routing issues, security issue, real time computing, QOS, hardware development and low cost fault tolerance networks.

1.4 Clustering Strategy

Clustering is the way to gather data from group of similar or different items. Clustering is necessary for sensor network applications where numerous ad-hoc sensors are deployed for sensing purposes. Clustering is one of the techniques used to

increase the life time of sensor network. By using clustering the energy consumption in nodes is greatly reduced [9].

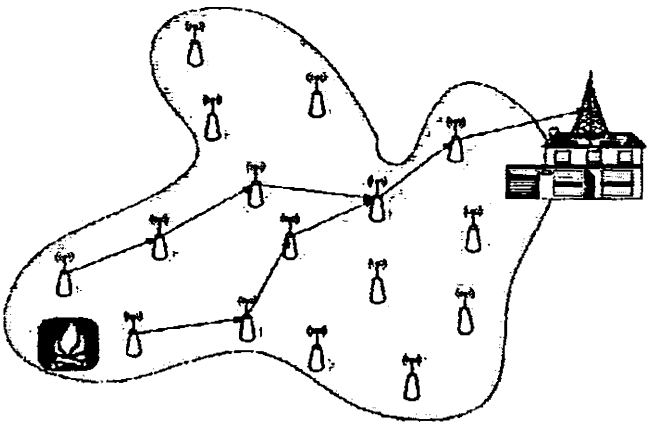

Figure 1-4: [9] Clustering Example

Figure 1-4 shows, through the interconnection of nodes, the data can route from node to node thus finally arrive at base station.

From the network architecture routing protocol can be dividing into two main classes. 1. Flat network routing, 2. Hierarchical network routing [7]

In case of flat network routing all nodes participating in the network have identical role. A node finds route hop by hop when it sends the data to other node in the network [7]. The advantage of this scheme is fairness and easiness whereas shortcoming of this scheme is lack of scalability followed by sustained packet overheads [10].

In hierarchical network routing scheme all participating nodes in the network play different roles. A framework is used for routing purpose. All nodes are divided into two categories. In the first category nodes performs sensing and transmission of data whereas the nodes in second group referred as cluster heads having their local information used in routing [10]. The benefit of this scheme is simplicity and scalability whereas the only shortcoming is its complicated structure.

With respect to routing scenarios clustering allows to spilt the data transmission into two classes i.e. inter-cluster communication and intra-cluster communication [7].This saves more energy in nodes. Member nodes only forward their data to their corresponding cluster head. A cluster head is only responsible for forwarding of data to base station.

1.5 Intra- cluster Communications

The intra-cluster communication is performed inside the cluster. In start most of clustering schemes presuppose one hop communication between member nodes to corresponding cluster heads [7]. All member nodes are at most two hops away from each other [7] Figure 1-5(a). The use of one-hop makes assortment of cluster head quite easy however this needs multihop intra-cluster connectivity at various time intervals. Multi-hop routing within cluster Fig 1-5(b) , has previously been proposed for both wireless and ADHOC networks [7].

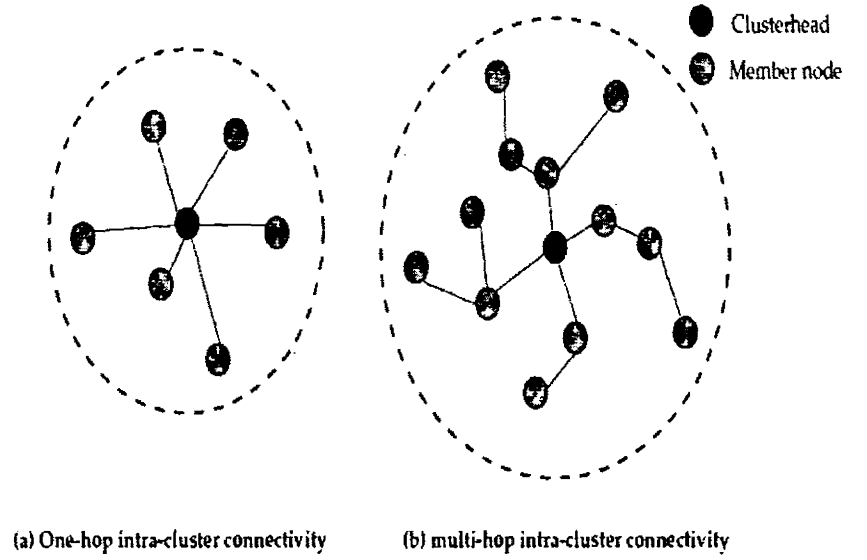

Figure 1-5: [7] Intra-cluster communication

1.5.2 Inter- cluster Communications

The inter-cluster communication occurs between the neighbor cluster heads or cluster heads to base station directly. Figure 1-6 shows this phenomenon where cluster head directly communicate with base station. Member nodes forward the data to their own cluster head that in turn communicate with base station. This is quite simple approach but not efficient in terms of energy consumption [7]. The distant cluster heads dissipates energy very soon due to larger distance from base station.

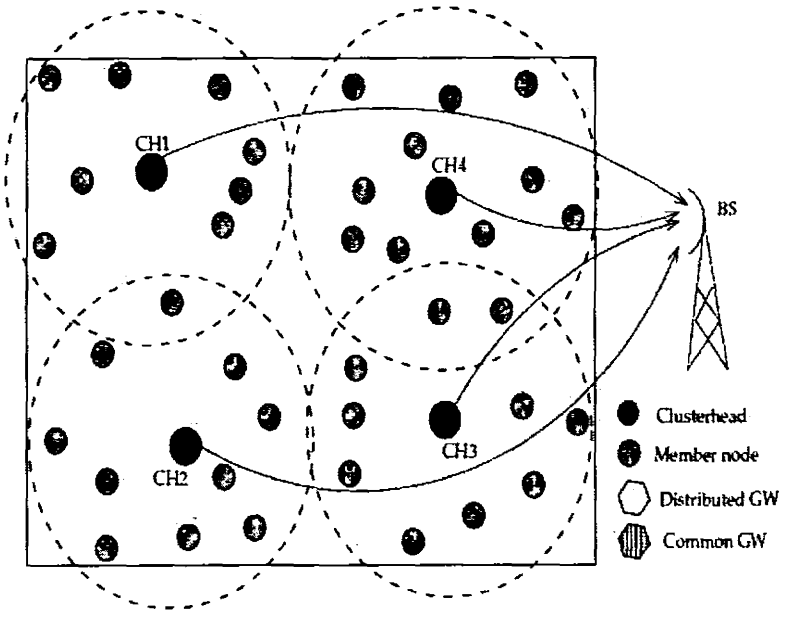

Figure 1-6: [7] one hop towards the sink

1.5.3 Clustering Advantages

Following are the key advantages of clustering [9].

1) By using clustering techniques routing path is reduced due to the availability of local path.

2) Clustering is used to avoid the unnecessary passage of messages among the nodes. Bandwidth is further saved and the member nodes only communicate with their corresponding cluster heads.

3) By employing diverse methods the battery life time is increased.

4) Nodes forward their data only to their corresponding cluster head, this reduces topology maintenance cost.

5) The replicas of data are reduced as data aggregation is only performed by cluster heads.

6) The rate of energy consumption in cluster head is further reduced by using sophisticated algorithms.

1.6 Problem Identification

As stated earlier, the wireless sensor network (WSN) comprised of tiny nodes. When every sensor node starts communication with other sensor nodes for data communication in network, great data congestion and collisions may occur. Energy

consumption in clustered WSNs is a major issue in today's research. A number of researchers have addressed this issue by developing of highly energy efficient schemes.

1.7 Contribution of the research thesis

We have developed an efficient clustering scheme aiming with the minimum loss of energy in nodes and cluster heads resulting in increased network life time.

1.8 Composition of the Thesis

The organization of this thesis is divided into chapters. In chapter 2 we will discuss the literature survey followed by the hierarchical clustering techniques with their pros and cons.

In chapter 3 the problem statement and problem scenarios are conferred. The chapter 4 includes discussion regarding our detailed proposed solution. The chapter 5 comprises discussion with reference to implementation of our proposed scheme. In chapter 6 the experimental results of our proposed scheme are presented and finally in chapter 7 we discussion about conclusion and future work is presented.

2

LITERATURE SURVEY

2. LITERATURE SURVEY

We have argued the contributions as well as the limitation of various researchers on clustering in wireless sensor network. The details of these are given as below.

2.1 LEACH [2002]

Motivation

LEACH (An Application-Specific Protocol Architecture for Wireless Micro sensor Networks) scheme suggests grouping of all nodes into clusters. One of the nodes is nominated as cluster head. The role of cluster head is to assemble data from all member nodes and forward it to sink node. According to this scheme network is alienated into clusters. Overall operation of this scheme is completed in rounds. In the first round the clusters are formed by using cluster setup phase followed by data transmission to base station called steady phase. In setup phase the clusters are constructed by election of cluster head. This action is performed by using an advertisement message that is passed between nodes. The decision to become cluster head is given probability 0, 1.

Those nodes that are willing to become cluster head can keep this message, or else will pass to neighboring node. The nodes that are cluster heads in first round can't become cluster head after (1/p-1) rounds [11]. After the completion of one round all nodes are once again are qualified to become cluster head for next round. Once the cluster head is elected all clusters are constructed. The cluster head node drains their energy faster compared to member nodes due to their heavier load. In order to balance energy the role of cluster head is rotated among all nodes.

The second phase is called steady phase in which data is transmitted to base station. In this phase all member node send their data to their corresponding cluster head. After receiving data cluster head aggregate data and forward to base station. This is shown in the Figure 2-1.

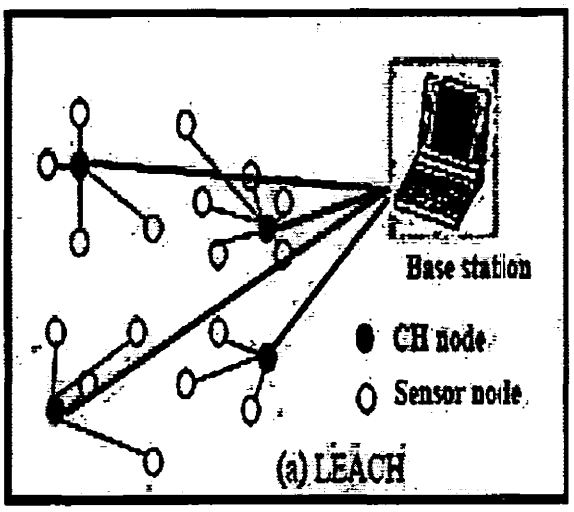

Figure 2-1: [11] LEACH Protocol

Limitations

1) If base station is far the cluster head nodes drain their energy at faster rate. This results as decline in network life time [11].

2) The drawback of this scheme is that it did not provide an efficient way for the distribution of cluster head due to random election of cluster head. The random election only depends on the probability for cluster heads election [27].

3) The author's assumption about the same energy consumption in cluster head is not true [27].

2.2 UCR [2007]

Motivation

UCR (An unequal cluster-based routing protocol in wireless sensor networks) authors designed and inter cluster routing protocol to prolong network life time.

The authors suggested that member nodes are grouped into different unequal sizes of clusters. The cluster size which is very near to base station is smaller compared to other clusters. These small sized clusters save more energy compared to the larger in clusters with large size. The cluster near to base station will not die earlier because of small number of available nodes that cluster. The process continues till cluster heads have been elected. Base station records all significant information for optimal path and multipath routing. Instantly all earlier sleeping node arouses and each of them chooses its nearest cluster head with higher signal strength. The node informs to

cluster head by using Join_clu message. On receiving this message the cluster head will made TDMA Schedule and transmit node into the cluster.

The energy consumption can be calculated by using greedy approach.

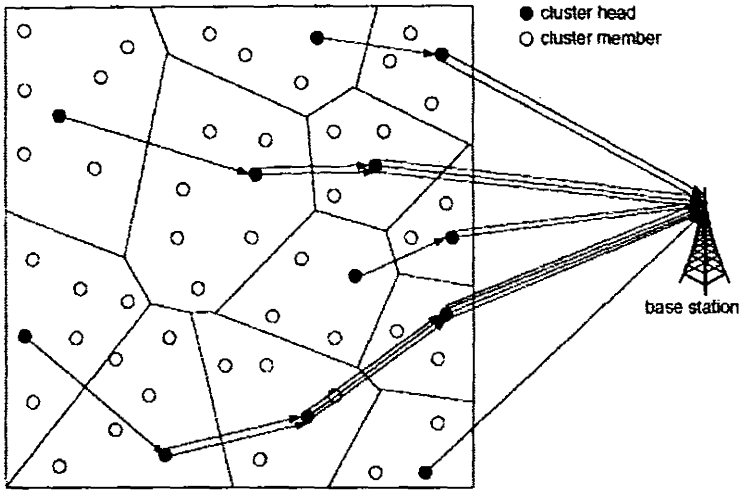

Fig. 1 An overview of the UCR protocol

Figure 2-2: [12] Unequal cluster based routing

Limitation

The drawback of this scheme is the range of cluster head that causes difficulty in communication with other. Hence the cluster heads utilize more energy to reach in middle of cluster heads [15].

2.3 EEHC [2009]

Motivation

EEHC (Energy efficient heterogeneous clustered scheme for wireless Sensor networks) is an energy efficient technique especially designed for HWSN. In this scheme each of the nodes has assigned certain weight. The nodes are selected as a cluster head based on certain probability. This algorithm is based on LEACH [22]. In LEACH nodes are selected as a cluster head on a finest percentage in each round. This algorithm works same as presence of heterogeneity of nodes.

In this scheme certain names are specified for nodes and referred as alive, normal nodes and super nodes. The super nodes have more energy than normal ones. The rest of nodes are called advanced nodes.

Authors deployed 100*100 m sensors field. They donate "O" for normal nodes, ""+" for advanced nodes and "*" for super nodes.

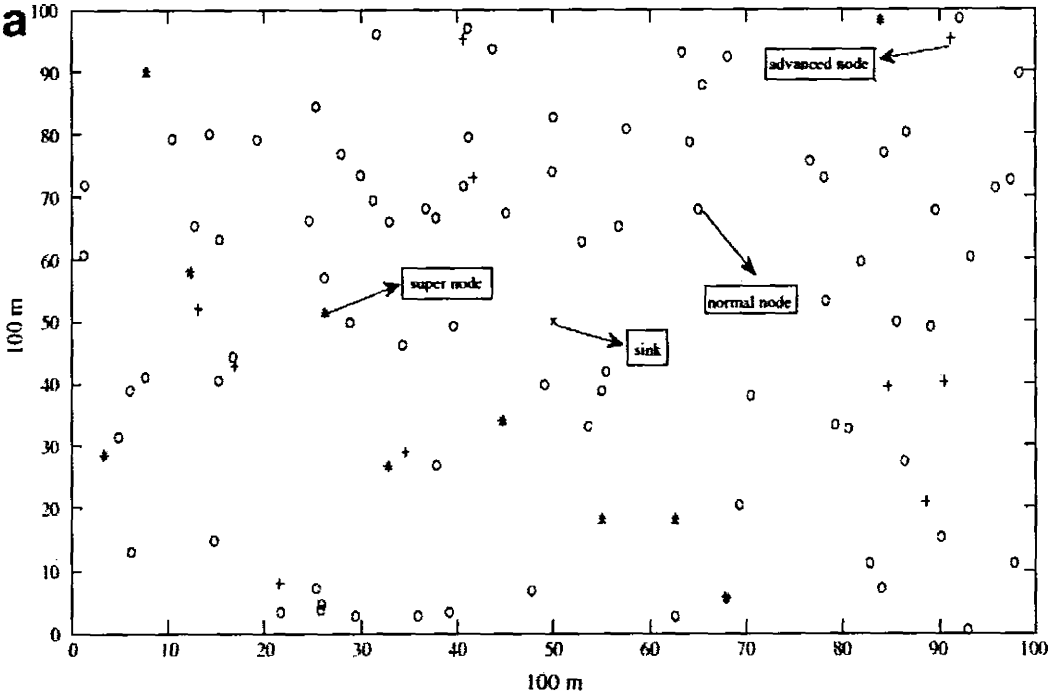

Figure 2-3 [22] EEHC: Network Structure all nodes are alive (a)

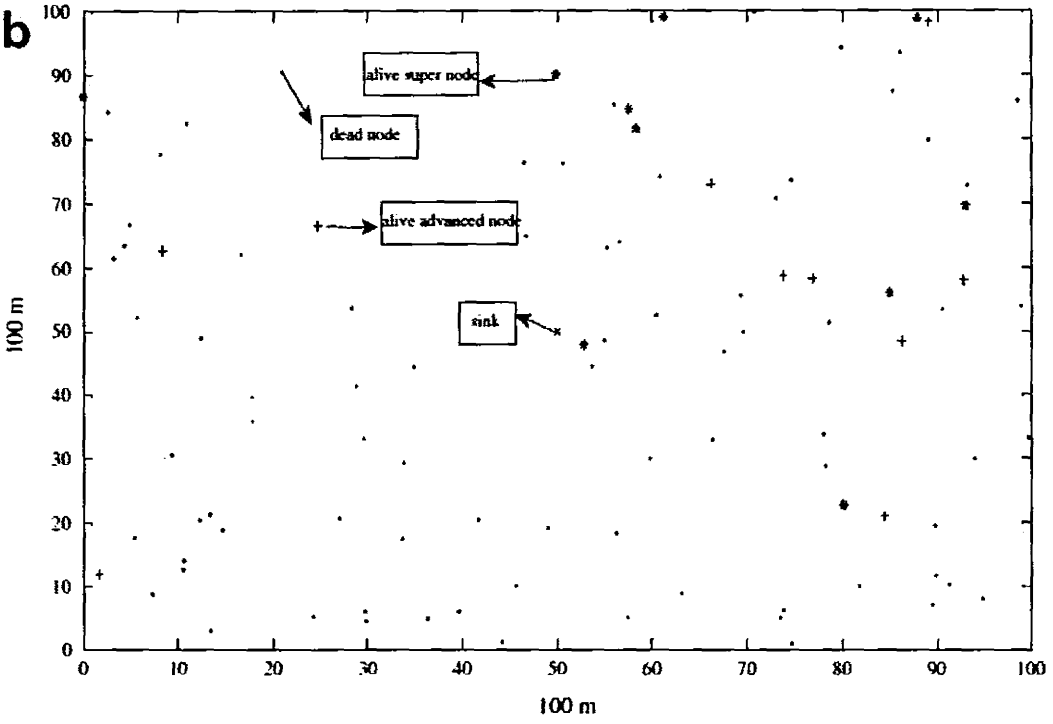

Figure 2-4 [22] EEHC: After some rounds some nodes died (b)

The node that depletes its energy is known as dead node. The first node that is died is shown in Figure 2-4.

The authors conclude from various experiments that normal nodes die earlier then the super nodes and later on the advanced nodes dies. At last rounds the advanced and super nodes remain alive [22]. The authors concluded at the end of experiments that the proposed schemes performed better for heterogeneous circumstances.

Limitation

In this scheme cluster heads are elected based on their weighted probability in reference to its initial energy. Each of member nodes or cluster head directly communicates with base station and hence due to larger distance they will drain their energy soon.

2.4 VLEACH [2009]

Motivation

The new version of LEACH [11] named as VLEACH (Improvement on LEACH protocol of wireless sensor network) is developed in order to overcome the drawbacks of LEACH [11] protocol. According to the authors the cluster head in LEACH protocol is always receiving data from its member nodes [18]. Hence due to heavy load on cluster head early death is expected. In VLEACH [11] multiple cluster heads are elected at the same time. Second cluster head is called Vice-CH. The role of vice cluster head is to serve as a cluster head when 1st cluster head dies.

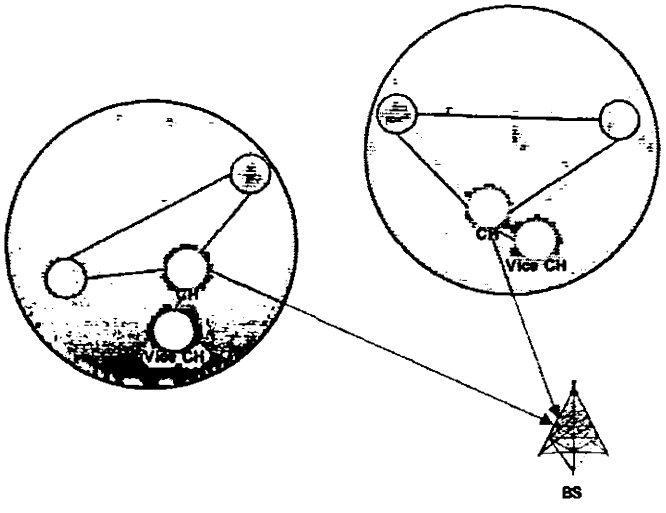

Figure 2-5: [18] VLEACH Cluster formation

According to the authors, there is no need to re-elect cluster head again and again. Due to the presence of Vice-CH the network life time is increased.

Limitation

This scheme does not provide any information about the exact number of cluster heads that are placed.

2.5 EAP [2009]

Motivation

EAP (An Energy-Aware Routing Protocol in Wireless Sensor Networks) is designed for heterogeneous environments [19]. EAP uses new parameter for election of cluster head. According to authors majority of cluster based protocol are not fully distributed. Likewise the cluster heads are not well distributed and thus the algorithms are not energy efficient [19].

In order to save more energy in nodes some algorithms only focus on their residual energy. This approach is not very efficient in heterogeneous environment. The probabilities of some nodes are greater than the residual energy of other nodes therefore the selected cluster head would die soon.

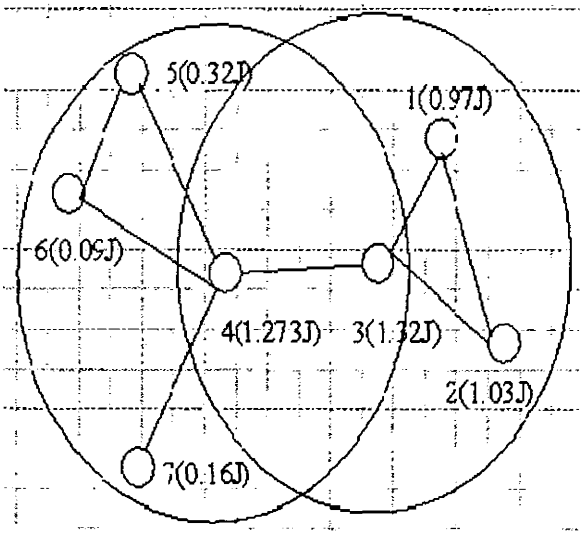

Figure 2-6: [19] EAP cluster formation

EAP solve this problem by using advanced parameters. The overall work of EAP [19] is divided into rounds. In setup phase the clusters are constructed and at steady phase the routing tree is constructed.

In setup each of nodes in network computes its Ea and time delay for each node. Any node non responsive during the specific time interval is not considered as cluster head.

At the steady phase each cluster head computes its weight by receiving the message [19]. If the computed weight is lower than the receiving message, it is referred to as child node. Each child node sends child_msg to corresponding parent node.

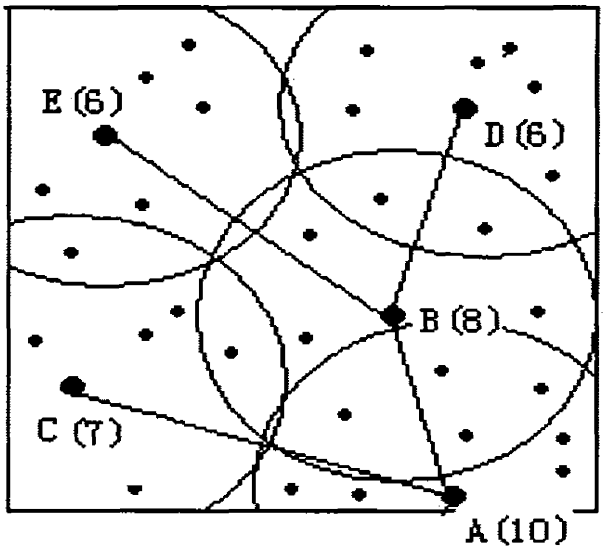

Figure 2-7: [19] EAP Tree Construction

Limitations

In this method the ratio of residual energy to the average residual energy is calculated by each node. The node with higher ratio has higher probability to become cluster head. This method does not provide good distribution of cluster heads as a result of message passing it has an overhead [28].

2.6 TBRP [2009]

Motivation

TBRP (TBRP: Novel Tree Based routing protocol in wireless sensor network) is a novel tree base routing protocol used to increase network life by using fuzzy based technique. The TBRP protocol is divided into two phases. At first phase clusters are made called cluster formation phase. In this case if energy in nodes is considered it is quite possible that some nodes are far-away from each other that result in dying of nodes. Likewise if only distance between nodes is considered then it is possible that

some nodes that are selected as cluster head are in low in energy, which results in loss of energy. The author proposes a fuzzy based method for cluster head selection.

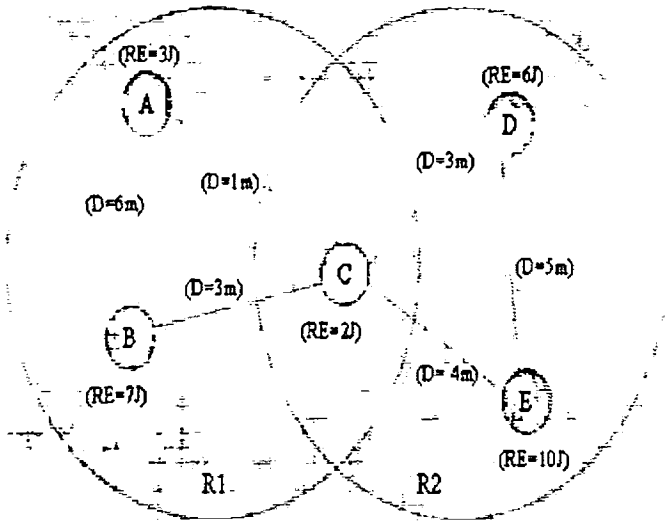

Figure 1. Cluster head election

Figure 2-8: [13] Tree Based routing protocol

Based on the computation of distance between two nodes and remaining energy of each node, a Fuzzy election number (FEN) number is allotted at the end of each round [13]. The higher priority fuzzy number is selected as cluster head. At last this fuzzy number is used for selection of parent node. The parent node constructs spanning tree and communicate with base station. This results as improvement of life time of network.

Limitation

The drawback of this scheme is that overall time is not considered for cluster formation and steady phase [30].

2.7 EMHR [2009]

Motivation

According to authors the EMHR (Energy- Efficient Multi-hop Hierarchical Routing Protocol for Wireless Sensor Networks) is developed to overcome the disadvantages in direct routing. LEACH supports only direct routing. It is possible that cluster head in LEACH is far away from base station and thus cluster head would die soon.

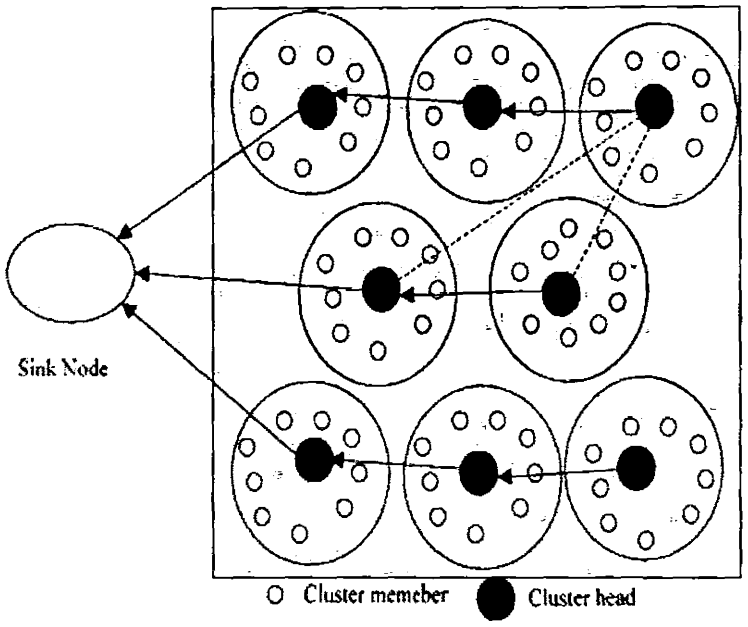

Figure 2-9: [26] EMHR topology Framework

In order to overcome above stated problem the EMHR [26] works in two phases. In first phase clusters are constructed. In cluster formation phase the cluster head is elected based on only higher energy. Second phase is called data transmission phase the EMHR scheme chooses a different next hop cluster head by using their advanced parameters "weight function". Each cluster head compute its own "weight function". Closeness to base station cluster heads and higher in "weight function" are responsible for data transmission. By consideration of energy and multihop cluster head to cluster head results in increasing network life time.

Limitations

1) Larger the distance between clusters heads more is the loss of energy.
2) Lack of Gateway nodes between cluster head nodes.

2.8 CBRP [2010]

Motivation

In CBRP (Novel cluster Based routing protocol in wireless sensor network) the authors attempted to increase network life time by proposing their advanced parameters. CBRP is different from all previous algorithms. Earlier algorithms are

based on only remaining energy parameter. But CBRP has manifested both distance and remaining energy. Hence energy consumption between nodes is reduced.

The operation of CBRP is dived into rounds [14]. 1st phase is called setup phase during which clusters are constructed. The cluster head election is performed by using message passing. Each node broadcast remaining energy RE message to all nodes. The cluster head is elected based on their proposed mathematical formula.

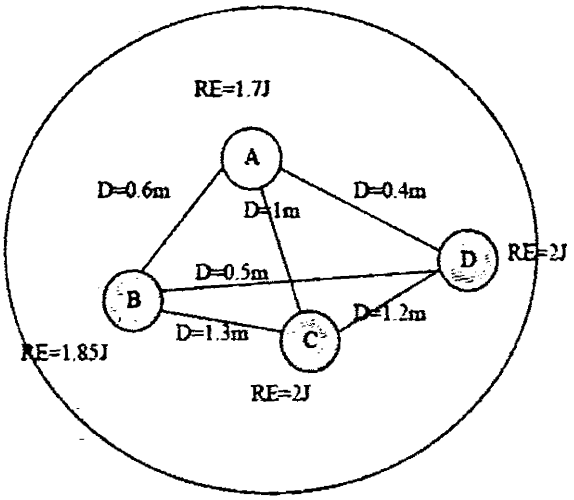

Figure 2-10: [14] CBRP Cluster head election

In each round cluster head selection value "CHV" of each node is calculated and the higher CHV is considered as cluster head for specific cluster.

The second phase is referred as steady phase in which routing tree is constructed. The data is transferred to base station. Each node computes parent selection value PSV using a mathematical formula and higher value of PSV is considered as parent node. Parent node is used for communication with sink node. At the end spanning tree is constructed and data is transmitted to base station.

Limitations

1) CBRP does not target distance between base stations, it is possible that some larger in distance nodes are elected as cluster head. This results in loss of energy. It is possible that in steady phase some nodes are elected as parent node in tree and hence due to high consumption of energy they will die soon [17].

2.9 SFRP [2010]

Motivation

SFRP (A Selective Flooding-based Routing Protocol for Clustered Wireless Sensor Networks) is especially designed for monitoring and environmental conditions [15]. SFRP is designed to overcome the drawbacks of direct cluster head to cluster head communication, which results in loss of energy. The overall work of SFRP is divided into two phases [15].These are cluster formation and data transmission phase. In cluster formation clusters are constructed using distributed clustering algorithm (DCA) algorithm. All nodes have assigned specific weights. The heaviest weight among nodes is considered as cluster head.DCA algorithm will give guarantee that no two cluster heads are neighbors. Figure 1.11 explains cluster formation of DCA algorithm.

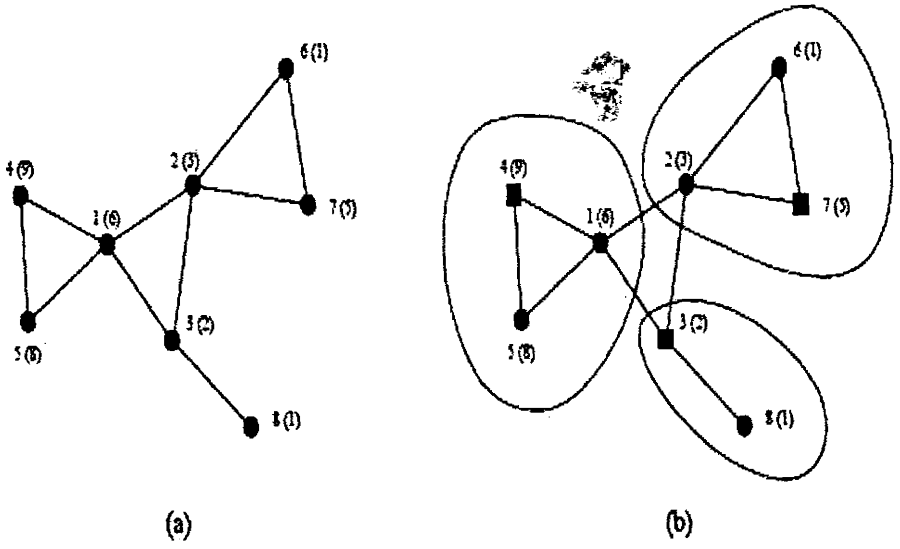

Figure 2-11: [16] DCA Cluster formation

The next phase is known as adjacent cluster discovery and gateway selection. After cluster construction nodes pass messages among them. Member node has information about their cluster head. Gateway node is considered if it has information regarding adjacent cluster head. At last spanning tree is constructed in steady phase.

Limitations

After cluster formation certain nodes are selected as cluster heads. These nodes keep doing more work as compared to the other nodes and hence will die soon resulting in short network life time [29].

2) During cluster head selection frequent cluster head changing process will results as degrading in performance [29].

3) Traffic bottleneck and single point failure at gateway nodes will degrade performance.

2.10 EHRP [2010]

Motivation

EHRP (Novel Energy-aware Hierarchical Routing Protocol in Wireless Sensor Network) is a cluster based protocol for wireless sensor networks. The objective of this scheme is that to save energy and network life time.

In previous cluster based schemes distance between cluster heads and base stations or distance between nodes and base station was not considered that resulted in loss of energy in cluster heads.

EHRP protocol works in two phases, cluster formation and data transmission. In cluster formation every node computes its own distance and base station. According to suggested formula based on remaining energy and distance between them, every node computes own CS (cluster selection formula). Higher value of CS is considered as cluster head.

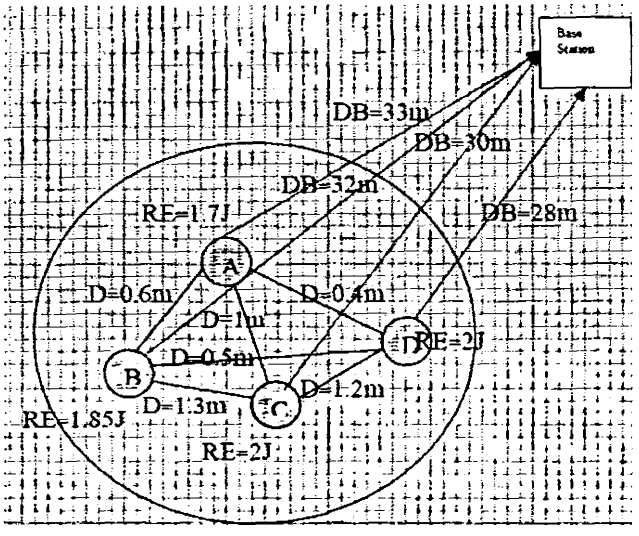

Figure 2-12: [17] EHRP Cluster formation

In steady phase every cluster head computes its own PN (parent node selection formula). Higher of PN is considered as parent node. Finally parent node is elected for data transmission to base station.

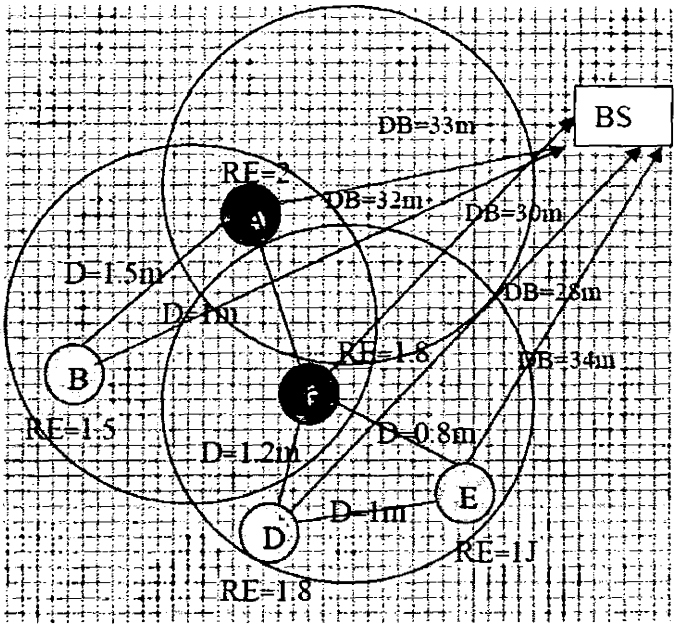

Figure 2-13: [17] EHRP Steady Phase

Limitation

1) Heavier load on cluster heads during data transmission phase.

We have discussed a number of reviewed papers in our literature survey. This is brief summary of most familiar literature with pros and cons.

Table 2-1: Approaches to Literature Reviews

S.No	Related To Our Work	S.No	Unrelated to Our Work
2.1	LEACH[11]	2.2	UCR[12]
2.4	VLEACH[18]	2.3	EEHC[22]
2.5	EAP[19]	2.6	TBRP[13]
2.7	EMHR[26]	2.8	CBRP[14]
2.9	SFRP[16]	2.10	EHRP[17]

LEACH [11] is the first hierarchical routing protocol developed for WSNs. LEACH [11] introduces randomized rotation of cluster head role among nodes. The constraint

of this scheme is that LEACH did not consider the state of neighbors in cluster head assessment. VLEACH [18] is an enhanced form of LEACH [11]. VLEACH [18] elects Vice-cluster head during cluster formation. The objective of Vice-cluster head is that whenever cluster head dies the Vice-cluster head works as a cluster head. VLEACH does not provide exact information about cluster heads nodes. EAP [19] is developed for heterogeneous circumstances and remaining energy is introduced for electing the cluster head. EAP [19] handles area coverage problem by using intra cluster converge approach successfully. The disadvantage of this scheme is that the ratio of residual energy to the average residual energy is calculated by every node in networks. All nodes are provided with higher chance to become a cluster head. This method has not proposed better distribution of cluster heads. In addition a lot of messages overheads in each round are faced. EMHR [26] is another improved form of LEACH [11]. The EMHR [26] divides its own work in two phases. EMHR performs data transmission phase by employing multi hop direct cluster head to cluster communication. The drawback of this scheme is that if the cluster heads are more far away from each other, they will die soon. SFRP [16] is developed to overcome the disadvantages of cluster head to cluster head communication. SFRP [16] divides its work into rounds. DCA [16] algorithm is used to select highest weight as a cluster head. Network life time is improved by incorporating of gateway node between cluster heads. The drawback of this scheme is that after cluster formation, cluster head nodes have burden of work as compared to other nodes. Due to heavy load they will die soon.

3

PROBLEM STATEMENT

3. PROBLEM STATMENT

The cluster head nodes dissipate their energy at a faster rate due to larger distance from each other thus resulting in shorting of network life time.

3.1 Problem Scenario

In the Figure 3-1, two clusters are shown by circles. This scenario shows communication between two clusters a, b respectively. The nodes i and j are presented as cluster heads in clusters a, b. The cluster heads i were selected based on only higher energy. The member nodes are shown inside of clusters. In this scenario cluster head i directly communicate with cluster head j.

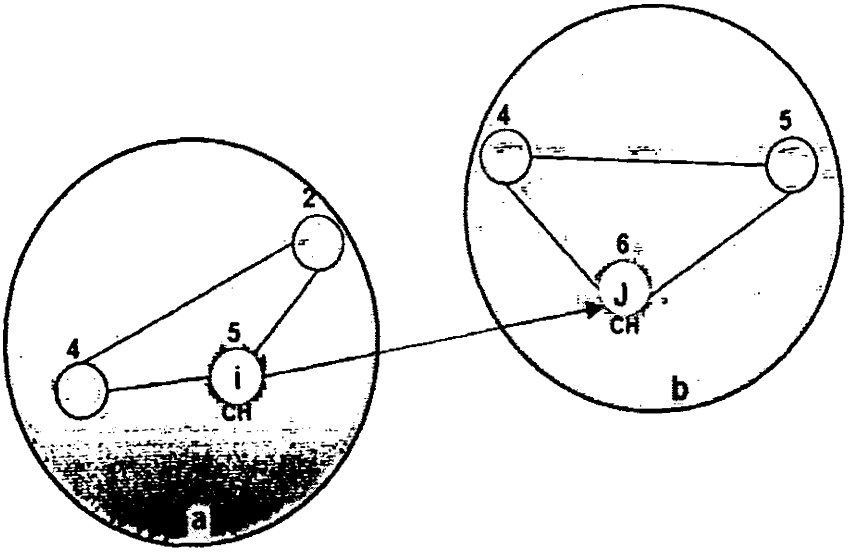

Figure: 3-1: cluster formation phase in existing scheme

In the Figure 3-2, cluster head i forward their data to cluster head j. Finally cluster head j is responsible for data transmission to base station.

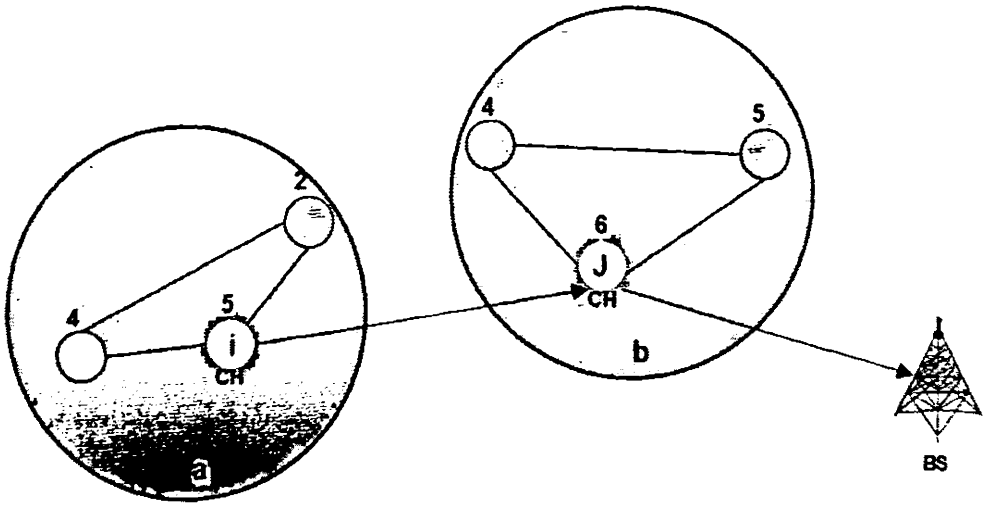

Figure: 3-2: Data transmission phase in existing scheme

In this scenario cluster heads are far away from each other. Due to larger in distance it is possible that cluster heads will have heavier load that in turn will cause the death of cluster head.

3.2 Research Objectives

1) Minimize loss of energy in cluster heads.
2) Extending life time of network.

4

PROPOSED SOLUTION

4. PROPOSED SOLUTION

In our research we assume a random deployment of sensor nodes in the field of coverage. Certain energies are assigned to each node. These energies are assigned by using Radio energy Model [25]. The distances between these nodes are computed by using of Euclidian distance. All nodes compute its distance with neighbor nodes and with the base station. The rest of details are as follows.

Consider number of nodes that are randomly deployed in network area in Figure 4-1. These nodes can communicate to other neighbor nodes by using message passing. For our easiness we assign them numbers with the range of 1-15.

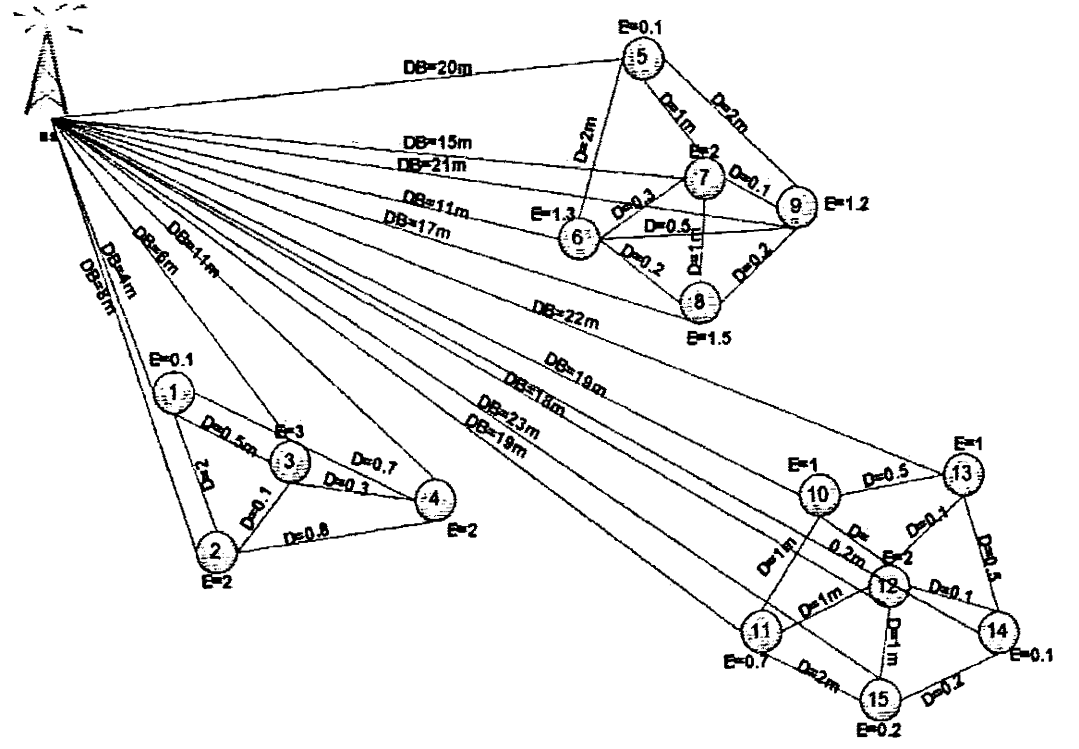

Figure 4-1: Node deployment in Network Area

The operation of our proposed scheme is further divided into two phases. In 1st phase cluster formation is completed and 2nd phase Data is transmitted to base station. The base station is plotted over (0, 0) in a (200,200) square Area A.

4.1 Energy Model

We have used radio Energy model as discussed earlier [25] for calculating of energy dissipation in different phases.

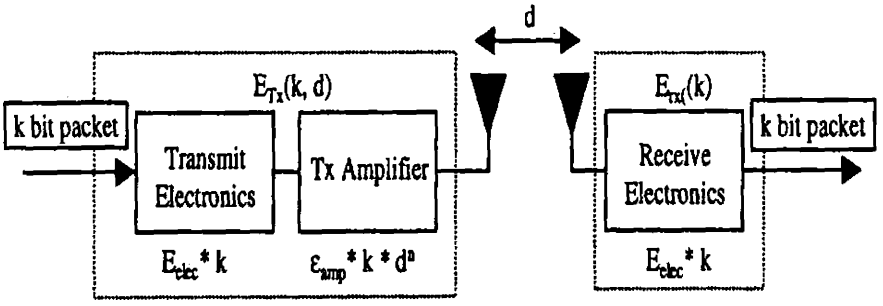

Figure 4-2: [25] Radio Energy Model

If transmission of k-bit packet message is desired with a distance "d" then the radio expends as follows.

$$E_{TX}(K, d) = \begin{cases} KE_{elec} + K\varepsilon_{fs}d^2 \; d < d_o \\ KE_{elec} + K\varepsilon_{mp}d^4 \; d \geq d_o \end{cases} \qquad (4.1)$$

Where E_{elec} is the energy dissipated in transmitter and receiver ε_{mp} is called amplifier energy. Amplifier energy is used to amplify weak signal during signal processing. E_{elec} is the electronic energy that depends upon the digital coding and modulation. The amplifier energy E_{elec}totally depends upon the distance factor. K is the number of bits that are transmitted to the base station.

D_o is the distance constant. In order to receive a message, the radio expends as follows.

$$E_{Rx}(d) = KE_{elec} \qquad (4.2)$$

4.2 Cluster Formation Phase

In cluster formation phase, all the nodes have same initial energy. The theme of cluster formation is to elect a cluster head among numbers of available nodes in a pool. For an optimal solution our technique considers the selection of cluster head, with largest surplus energy. Same as EMHR [26] cluster formation is completed in number of rounds. The mathematical formula for selection of cluster head is as follows.

$$T(n) = \frac{S(i).E}{(1-S(i).E)*(rmod\frac{1}{S(i).E}))} \qquad (4.3)$$

Where $T(n)$ is the number of competent nodes available for cluster head election in the pool. Where, $S(i).E$ is called remaining energy. Let i be the node with higher energy. A node is said to be a cluster head when$i > T(n)$. All nodes use message passing for communication purpose. If message receiving node has lower energy then this will send join message to nearest neighboring cluster head. If receiving node is already a cluster head then it do not have any need to pass any message. Upon completion of each round if node drains their energy then this type of node is called dead node. This node is not eligible to be elected as cluster head.

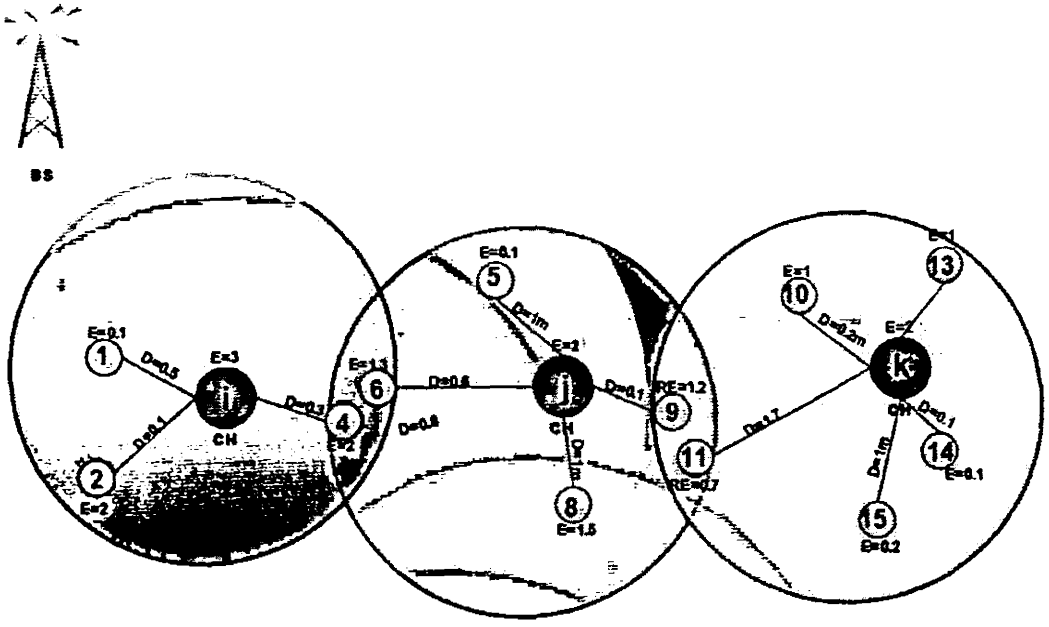

Figure 4-3: Cluster Head Election in Proposed Approach

Figure 4-3 explains the framework of cluster formation phase. There are three clusters constructed during cluster formation. Each of these clusters has a boundary that is shown by a circle. After cluster formation has taken place, the cluster head is selected according to our proposed scheme. The member nodes join their own nearest cluster heads as shown by using i, j, and k. The nodes that are neighbor to adjacent cluster are called gateway nodes. These nodes are indicated on boundary of adjacent cluster head.

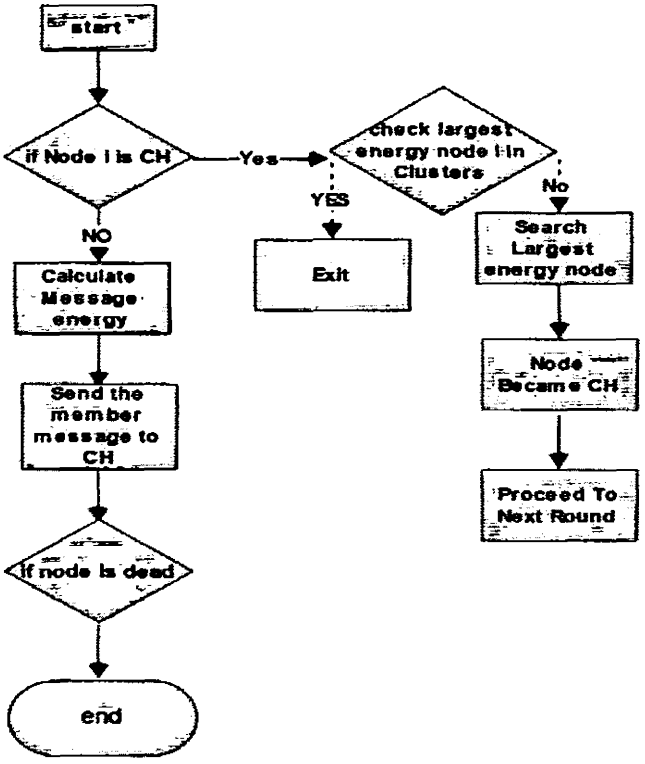

Figure 4-4: Flow Diagram of Cluster Formation

Figure 4- 4 is the explanation flow diagram of cluster formation in our proposed scheme.

4.3 Data Transmission Phase

In multihop routing the cluster heads directly communicate with neighboring cluster head for data transmission. A possibility exist that cluster head is far away from adjacent cluster head that results in energy depletion in cluster heads. Figure 4-5 shows the evidence of energy depletion in cluster heads due to larger distance.

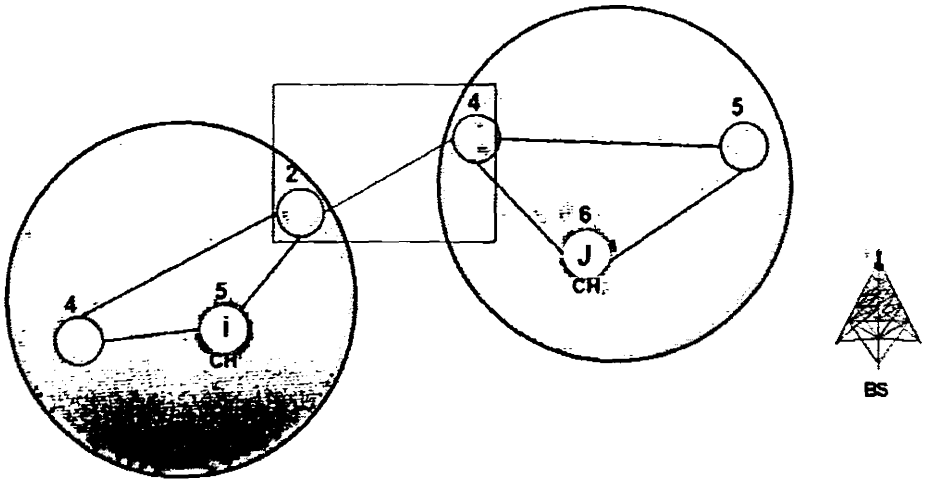

Figure 4-5: Energy depletion in farther cluster heads

In order to resolve this concern, we propose incorporation of gateway nodes instead of direct communication that results in marked decrease in the rate of energy dissipation in cluster heads. In our proposed scheme the member nodes within a cluster forward their data to corresponding cluster heads. The cluster head further finds appropriate gateway node for communication with adjacent cluster head. The distance computation is performed by using energy model [25].

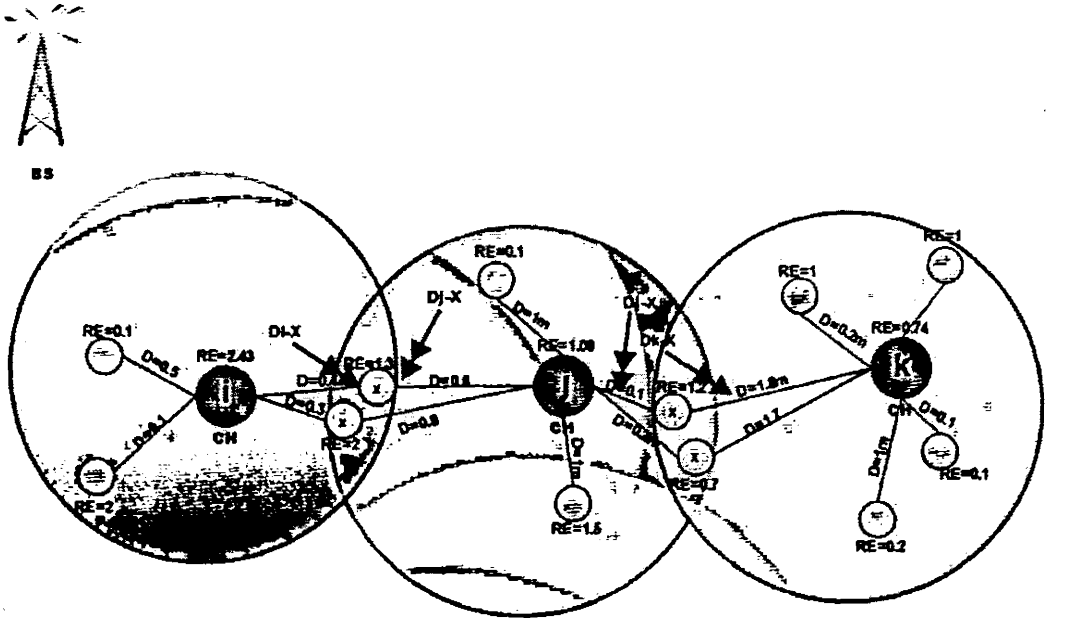

Figure 4-6: Data Transmission Phase, Gateway Selection in Proposed scheme

Figure 4-5 shows our proposed energy efficient scheme for wireless sensor networks. The neighboring nodes adjacent to neighbor cluster head are called gateway nodes. We have used these nodes for communication with adjacent cluster.

We assume that distance between cluster head i, and adjacent cluster head j is d(i , j). Distance between cluster head i to its neighbor nodes d (i , x), and adjacent cluster head j to its neighbor nodes is d(j, x). The distance between cluster head i to sink node is d (i, s) and adjacent cluster head j is d (j, s). We use a mathematical following formula for gateway selection.

$$\mathbf{G(i,j)} = [\frac{\mathbf{S(i).E}}{\mathbf{S(i).Max}}] + [[\mathbf{d(i,j)^2 + d(i,x)^2 + d(j,x)^2 + \frac{d(j,s)^2}{d(i,s)^2}} \quad (4.4)$$

The parameter of our equation is as follows. $\mathbf{S(i).E}$ is the remaining energy of cluster head i. The initial energy of cluster head i is $\mathbf{S(i).Max}$. Where $\boldsymbol{D(i,j)}$ is the distance between cluster head i and j. The $\boldsymbol{D(i,x)}$ is considered as distance of cluster head i to its neighbor nodes and $\boldsymbol{D(j,x)}$ is the distance between cluster j to the neighbor cluster head nodes.

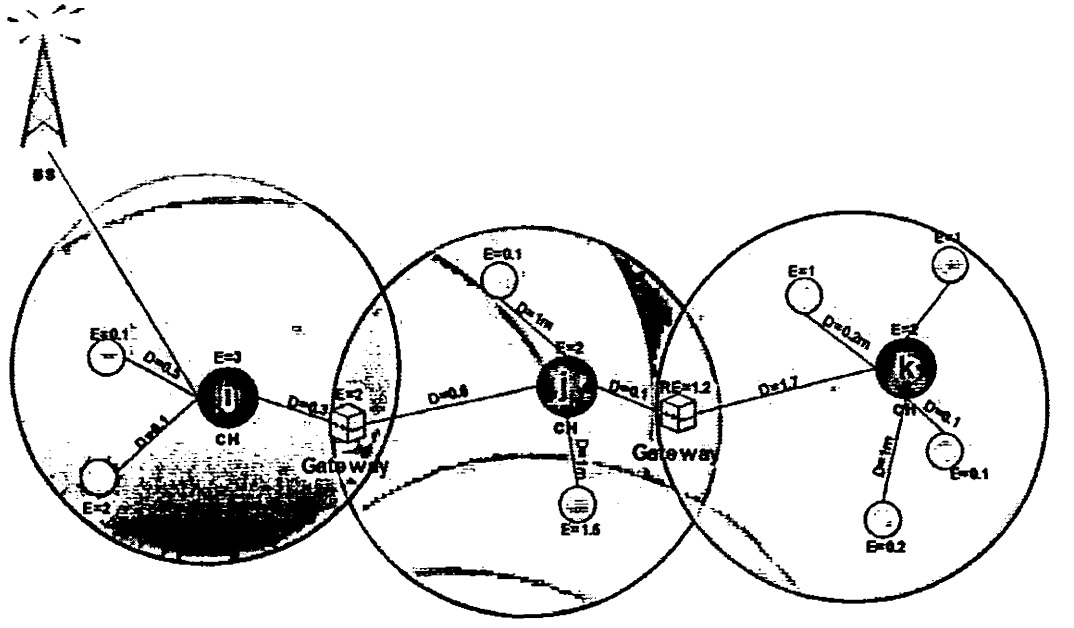

Figure 4-7: Data Transmission Phase: after Gateway selection in proposed scheme

In each round every cluster head computes "gateway function" whereas the highest is considered as gateway node for communication with adjacent cluster head.

We ensure that by using this protocol the constant selection of gateways finds next hop cluster head and is much more efficient than EMHR [26] scheme. Finally the cluster head close to base station will forward all data to sink. This approach results in enormous decrease in energy consumption in cluster heads and increasing of network life time. Further effects can be examined in simulation chapter 5.

4.4 Flow Diagram

Figure 4-8 shows the flow diagram of Multihop CH-CH data transmission phase.

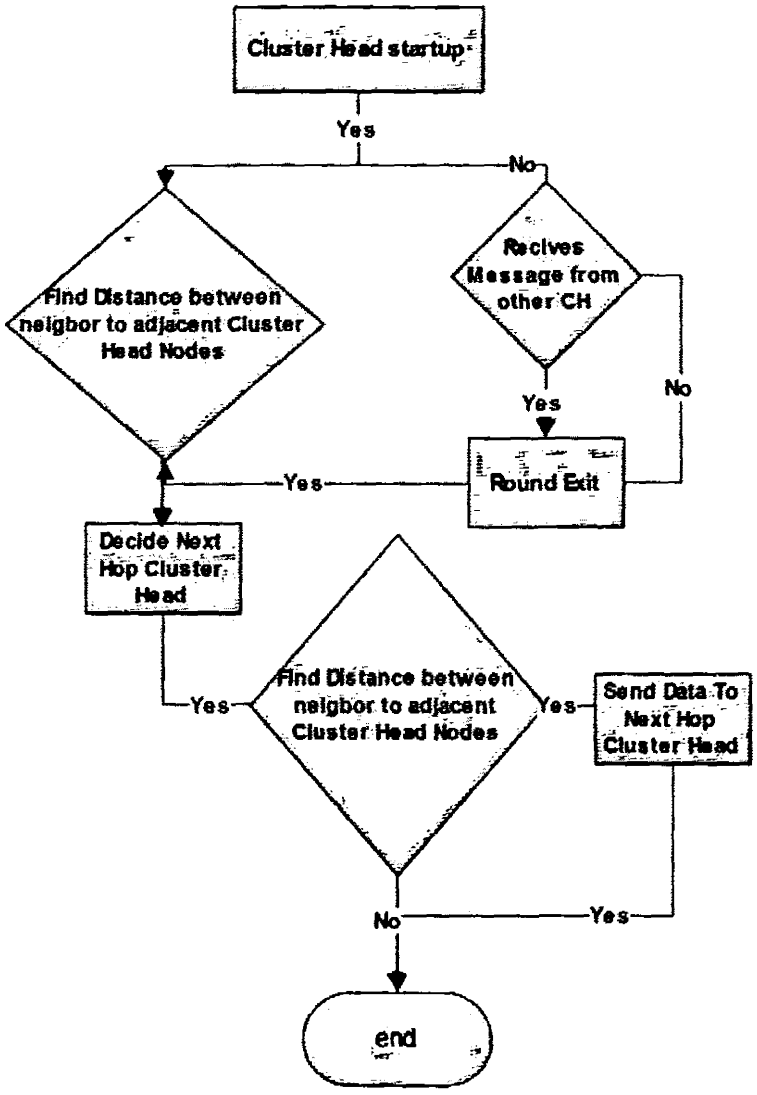

Figure 4-8: Flow Diagram of Data Transmission Phase in Proposed scheme

4.4 Simulate the Proposed Scheme

The proposed model is simulated in Matlab version R2009a. After simulation the proposed model is compared with the exiting scheme EMHR [26] and LEACH [11]. We have carried out a multiple of experiments for validation of all these schemes. The results of all the schemes were measured based on network life time, energy consumption in nodes, and energy consumption in cluster heads. These experiments and the results are presented in chapter 5.

5

IMPLEMENTATION

5. IMPLEMENTATION

In this chapter we have discussed the implementation and details of our research work. Assumptions and suggestion are clearly explained and discussed. Firstly the implementation of LEACH [11] is discussed followed by discussion regarding existing and proposed schemes respectively.

5.1 Implementation Environment

We have used Matlab version R2009a as working environment for Wireless Sensor Networks. Matlab is a high performance language used for technical computing. Matlab is used in programming, visualization with a user friendly environment. This means that problems and solutions are spoken in generally familiar mathematical notations. Familiar uses of Matlab are algorithm development, data analysis, exploration, visualization, scientific and engineering graphics.

5.2 Simulation Process of direct routing

For comparison purposes we have used LEACH [11]. We have deployed 25 numbers of nodes in square area A. we have assigned equal energies to the nodes. The deployment of nodes and all other parameters are fixed.

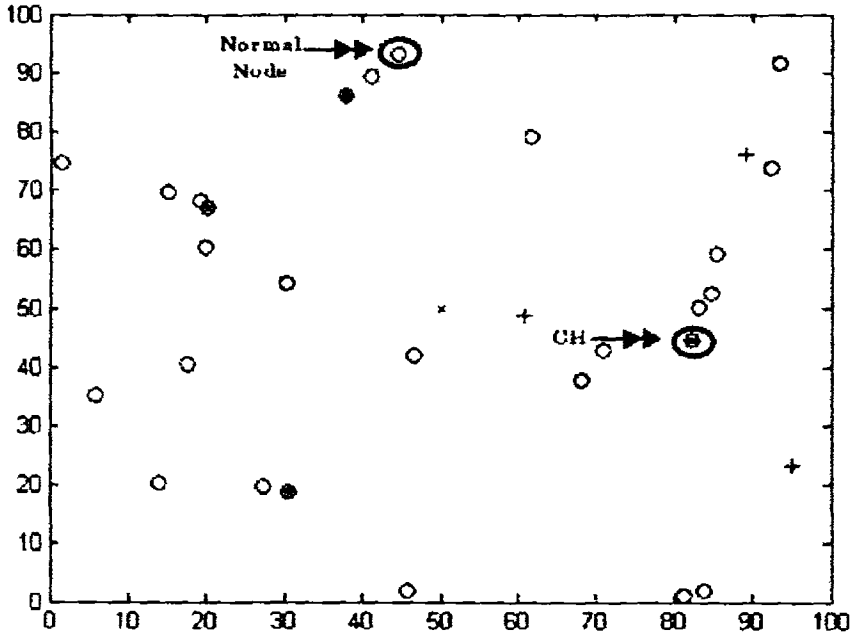

Figure 5-1: Simulation of LEACH

The normal nodes and cluster heads are indicated by arrows in Figure 5-1. The cluster head in LEACH is selected based on the occurrences of probability. After experimenting 20 numbers of rounds, total five clusters were constructed. Each cluster has its own cluster head. The role of cluster head is that to aggregate data from its normal member nodes. These cluster heads directly facilitate data transmission to base station.

5.3 Simulation Process of Existing Scheme

We have deployed 25 numbers of nodes in certain area A. Our simulation process is based on firm number of rounds. After completion of specific number of rounds the nodes are classified as cluster head, dead nodes and normal nodes. These are indicated by using different arrows as shown in Figure 5-2. After this experiment there were four numbers of clusters formed.

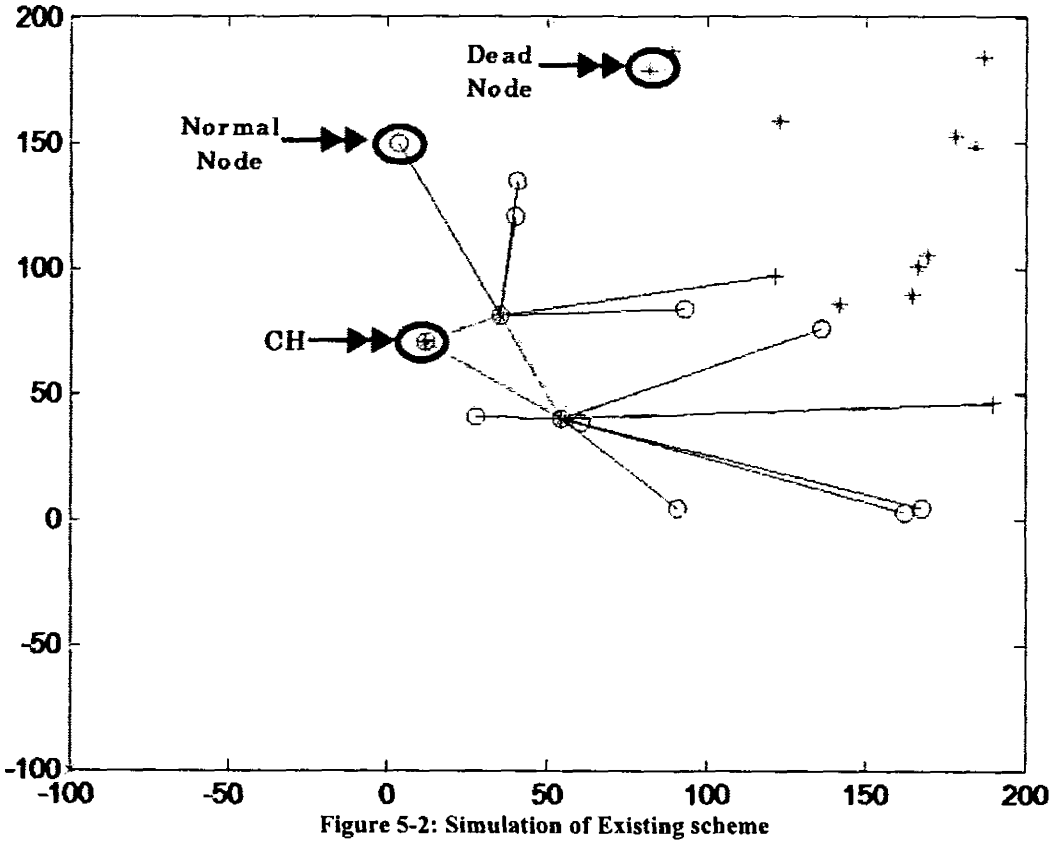

Figure 5-2: Simulation of Existing scheme

Certain node depletes their energy after the completion of each round. These are called dead nodes. These dead nodes are presented in graph shown above. In this

simulation existing scheme perform multihop cluster head to cluster head routing instead of direct routing. Due to cluster head to cluster head communication, ratio of energy consumption is lower than the LEACH [11].

5.4 Simulation Process of Proposed Scheme

To implement our proposed idea we used same 25 numbers of nodes in certain area A. Three type of nodes are mentioned in screenshot of our simulation in Figure 5-3.

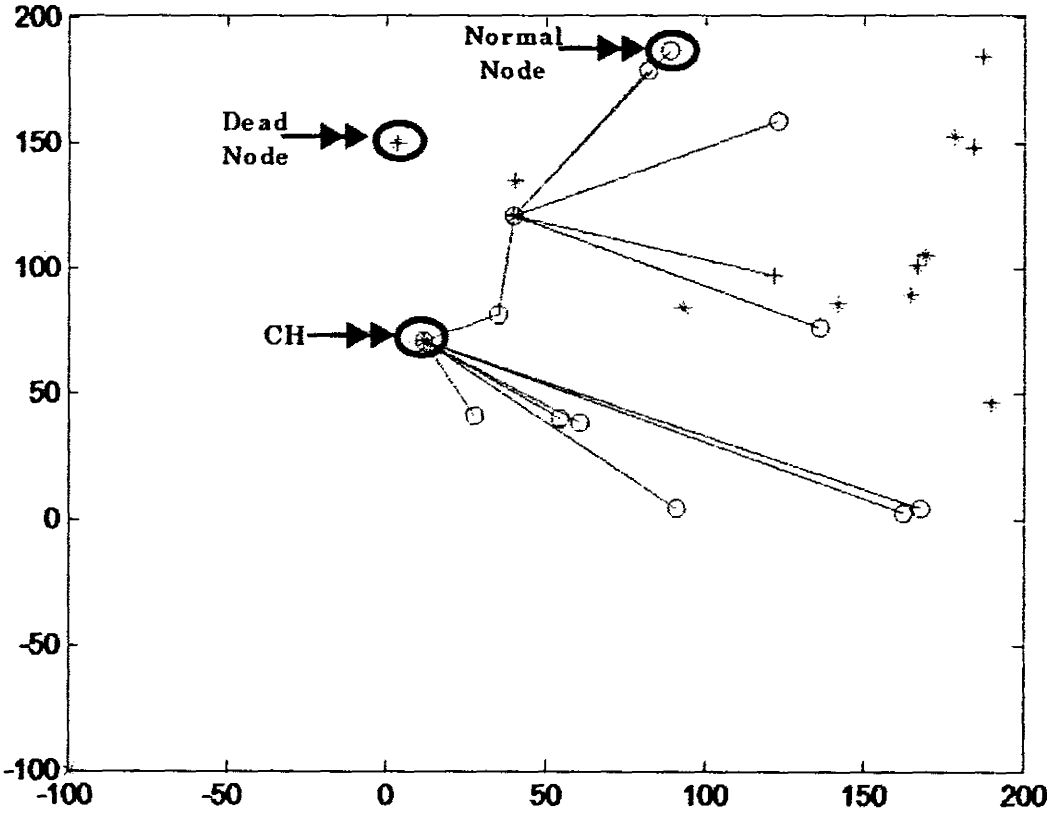

Figure 5-3: Simulation of proposed scheme

These are normal nodes, cluster heads and dead nodes. The normal nodes are those nodes that have been assigned certain energies. Initially all nodes are said to normal nodes. The normal node is represented in above Figure 5-3.

One leader among these nodes is selected, which is called cluster head. The cluster head is elected from number of normal nodes and has more energy than normal nodes. Due to advanced selection parameters in cluster formation, the cluster head is exceedingly energy efficient. Dead nodes are represented in Figure 5-3.

5.5 Parameters for Simulation and Tests

We have performed a multiple of experiments by simulating different scenarios and using different parameters.

- All nodes have been assigned the same initial energy.
- The distance computation is performed by energy module [25].

The tests are stated below and results are shown in next chapter.

5.5.1 Test No. 1

Our first test is the measure of energy consumption in nodes per round in time. We use 10-500 numbers of nodes for simulation purposes. Firstly we deploy 10 numbers of nodes for all the three schemes. A scheme is said to be energy efficient if it consumes low energy as compared to others. Correspondingly we increased the number of nodes from 20 to 500. The table below contains the list of parameters considered for simulation. The results obtained by using these experiments are discussed in next chapter.

Table 5-1: Simulation Parameters – Test No. 1

Value	Parameters
200,200	Network field
10, 500	Node Numbers
0, 200	Sink position
0.01j	Ethreshold
50nj/bit	Eelec
10nj/bit/m^2	Efs
0.0013pj/bit/m^4	Eamp
3J	Initial energy
5nj/bit/signal	Eda
20	No of Rounds
10 minute	Simulation Time

5.5.2 Test No. 2

The second test involves the measurement of network life time. We considered the network life time while first node in the network dies. We used our test by increasing simulation area 100*100 m^2. We have used 300 numbers of nodes for all the three schemes. We considered time in terms of death of first node followed by 50% and

100% nodes death in network. Table 5.2 shows the parameters of simulation considered for this test.

Table 5-2: Simulation Parameters – Test No. 2

Value	Parameters
100*100	Network field
300	Node Numbers
0, 200	Sink position
0.01j	Ethreshold
50nj/bit	Eelec
10nj/bit/m^2	Efs
0.0013pj/bit/m^4	Eamp
0.05J	Initial energy
5nj/bit/signal	Eda
10-400	No of Rounds
10 minute	Simulation Time

5.5.3 Test No. 3

The theme of this test is to measure energy consumption in cluster heads in number of rounds. The basic theme of this test is that to measure energy consumption in cluster heads. A scheme is energy efficient if it has low rate of energy consumption in cluster heads. Table 5.3 contains the parameters considered during this test and all the parameters are kept constant.

Table 5-3: Simulation Parameters - Test No. 3

Value	Parameters
200,200	Network field
100	Node Numbers
0, 200	Sink position
0.01j	Ethreshold
50nj/bit	Eelec
10nj/bit/m^2	Efs
0.0013pj/bit/m^4	Eamp
3J	Initial energy
5nj/bit/signal	Eda
1-20	No Rounds
20 minute	Simulation Time

5.5.4 Test No. 4

This test is used to show the efficient cluster formation effects. By increasing network field size we measured its effects on number of clusters that are produced. The theme of this test is "a scheme is said to energy efficient if it produces less number of clusters" when all the parameters are kept constant. Table 5.4 contains the parameters considered for this test.

Table 5-4: Simulation Parameters - Test No. 4

Value	Parameters
10-70	Network field
100	Node Numbers
0, 200	Sink position
0.01j	Ethreshold
50nj/bit	Eelec
10nj/bit/m^2	Efs
0.0013pj/bit/m^4	Eamp
3J	Initial energy
5nj/bit/signal	Eda
20	No Rounds
20 minute	Simulation Time

5.5.5 Test No. 5

In this test we increased the number of nodes from 10 to 60 with the aim to evaluate its effects on this on cluster formation process. The theme of this test is "a scheme is said to energy efficient if it produces less number of clusters" when all the parameters are kept constant.

Table 5-5: Simulation Parameters - Test No. 5

Value	Parameters
100,100	Network field
10-60	Node Numbers
0, 200	Sink position
0.01j	Ethreshold
50nj/bit	Eelec
10nj/bit/m^2	Efs
0.0013pj/bit/m^4	Eamp
3J	Initial energy
5nj/bit/signal	Eda
20	No Rounds
20 minute	Simulation Time

6

EXPERIMENTAL RESULTS

6. EXPERIMENTAL RESULTS

In this chapter we have discussed the results of pervious implementation chapter. All relevant supporting graphs with supporting material have been discussed in this chapter. All the objectives that we have described in the previous chapter have been achieved. These are shown in this chapter by using graphs.

In our solution we proposed to use the gateway nodes for communication with adjacent cluster head. In existing approach only cluster head is responsible for direct communication with the neighbor cluster head. If the cluster head is far-away this results in loss of energy. According to our suggestion the network life time is increased. Further results can be viewed on impact of cluster formation process.

6.1 Parameters for comparisons

These parameters are used for the comparison purpose.

6.1.1 Energy Consumptions in Nodes

Graph in Figure 6-1 shows the energy consumption in nodes for 20 numbers of rounds for all the three schemes. The consumed energy is measured in Joules.

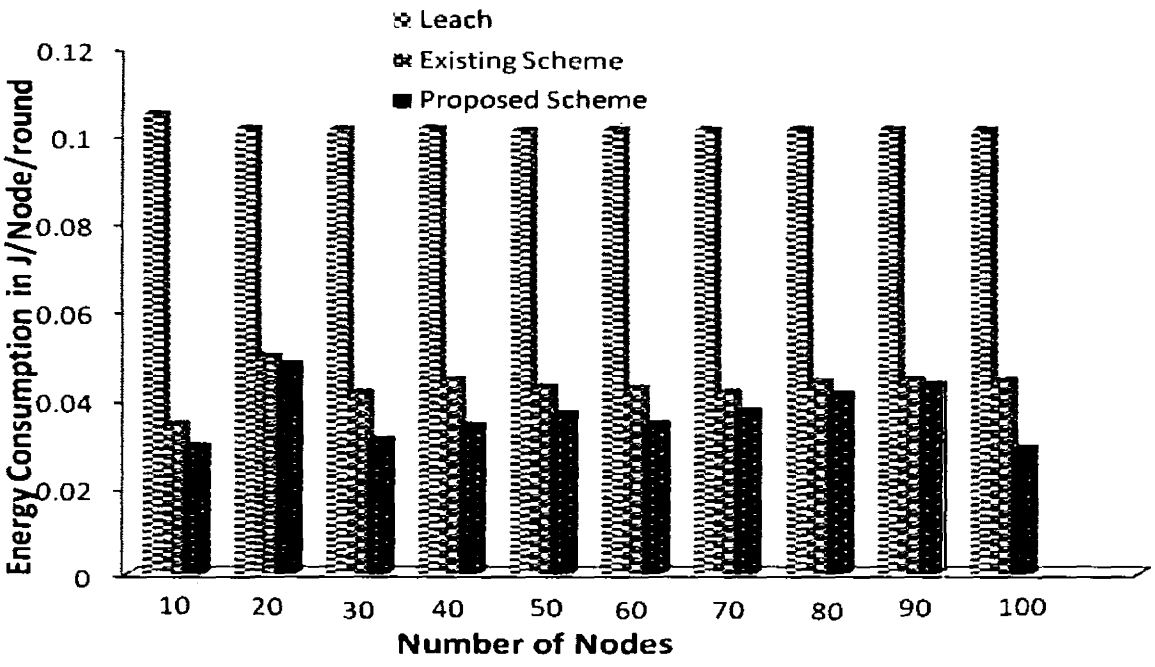

Figure 6-1: Energy Consumption in Nodes

As shown in above figure the energy consumed by each node per round of our proposed scheme is lower than the both schemes. At first we simulate all three for 10-100 number of nodes. The energy consumption in LEACH [11] is higher than both two schemes. The reason is that LEACH adopts direct single hop routing. Cluster heads in LEACH send their data directly to base station. If the cluster head is far-away from base station, due to larger distance cluster heads will lose their energy very soon. Likewise in existing scheme multihop routing is performed by using direct cluster head to cluster head communication. So energy consumption of this scheme is lower than LEACH. Our proposed scheme utilizes low number of energy in cluster heads, because we propose multihop routing by incorporating gateway nodes between cluster heads.

6.1.2 Network Life Time

Graph in Figure 6-2 shows the total network life of a network.

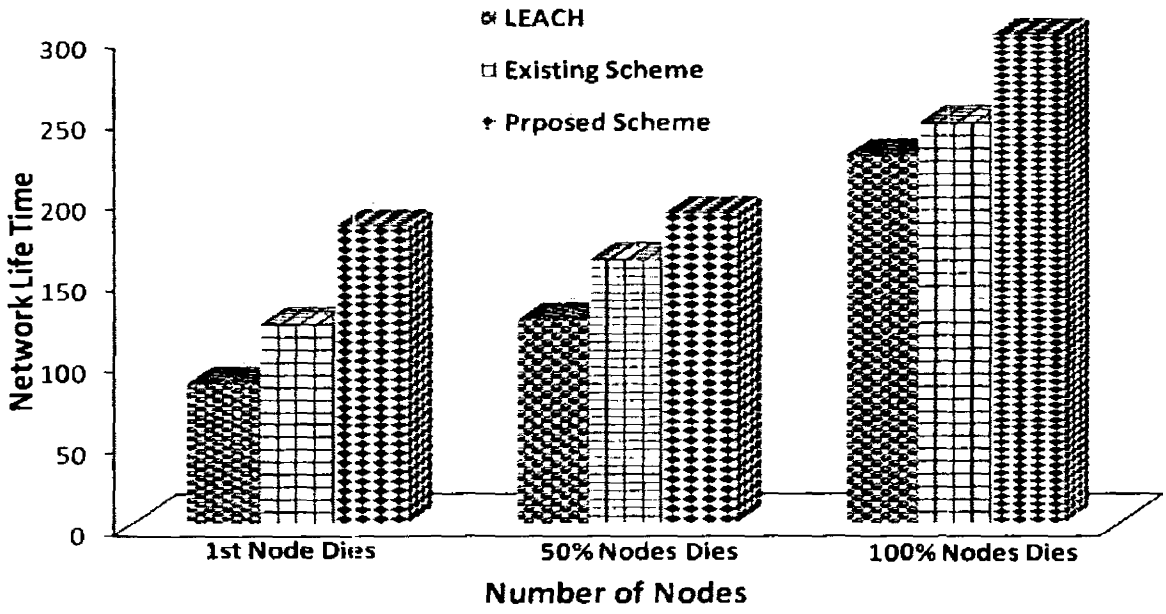

Figure 6-2: Network Life Time

Figure 6-2 shows the network life time of LEACH, existing scheme and our proposed scheme with the 300 number of nodes. We have computed network life time when first node in the network is dying. For simulation purpose we have used 100*100 m^2 as network area. We have used set of different time interval when first node in the network dies. These are followed by when 1^{st} node dies 50% and 100% node dying.

During the simulation it was noticed that time when LEACH first node dies at 86 numbers of rounds. Existing scheme prolongs network larger than LEACH [11]. The first node dies at 122 numbers of rounds in time. The proposed scheme stays longer time because its first node dies at 182 numbers of rounds. Same experiment is repeated over 50 % of nodes and 100% of nodes were dying. After comparing all the three results it was confirmed that our proposed scheme has longer network life time as compared to existing scheme.

6.1.3 Energy Consumptions in Cluster Heads

Graph in Figure 6-3 show the energy consumption in cluster heads per round for 100 numbers of nodes.

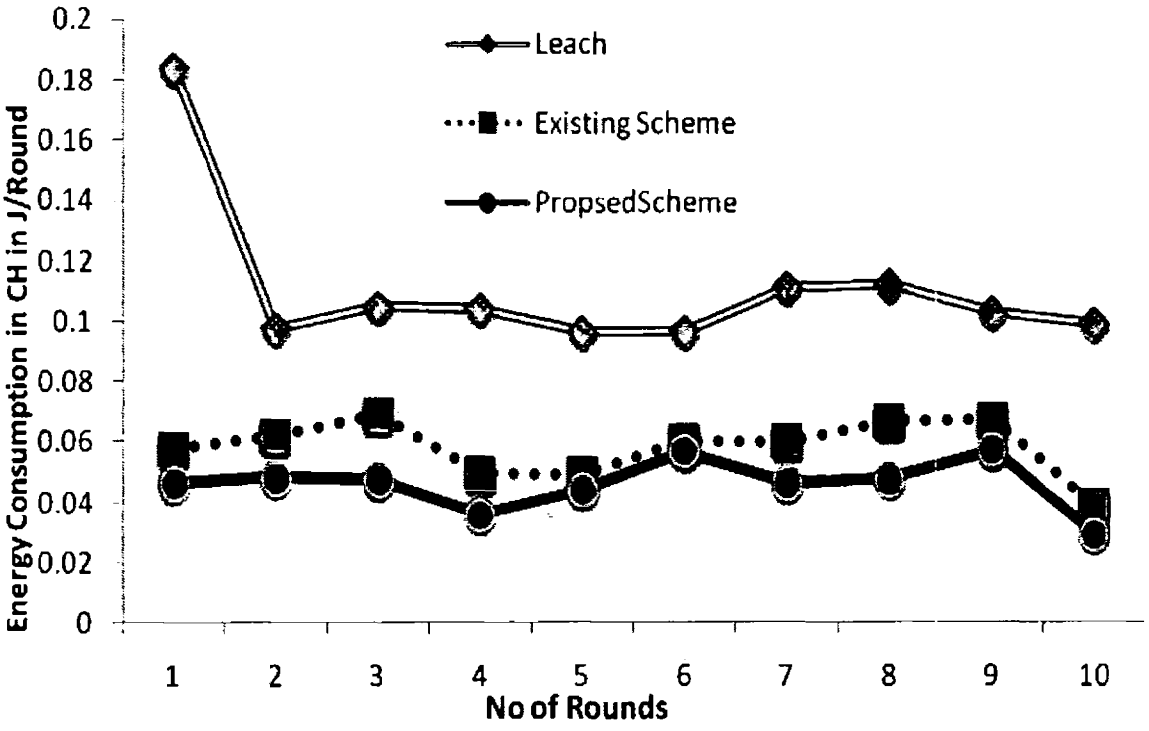

Figure 6-3: Energy consumption in cluster heads

Figure 6-3 shows that loss of energy in cluster heads is larger in LEACH per round. Existing scheme has low rate of energy consumption comparison with LEACH per round. Proposed scheme has much more low rate of energy consumption as compared to both schemes. This is due to the fact that it carries out multihop routing by gateway nodes.

6.1.4 Effects in Cluster Formation

In these results we have discussed the effects of our proposed scheme in especially cluster formation process.

Fig 6-4 shows the efficient cluster Formation (a) 20 number of rounds for the deployment of 10-60 numbers of nodes.

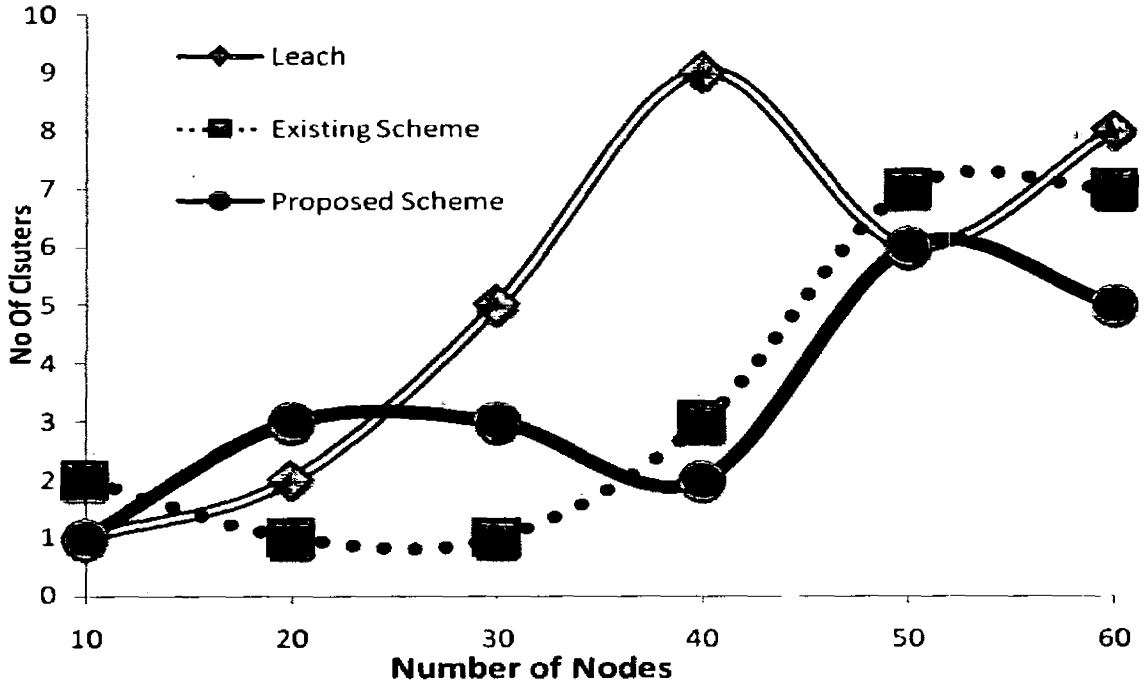

Figure 6-4: Energy efficient cluster formation (a)

In this case we gradually increase number of nodes in order to check its effect over cluster formation. A scheme is considered as highly energy efficient when it produces less number of clusters by increasing number of nodes. Our proposed scheme firstly produces higher number of clusters however upon gradual increase in the number of nodes it produced fewer numbers of clusters compared to the both schemes. In this experiment the LEACH produced higher number of clusters compared to both schemes. We repeated this experiment up to 60 numbers of nodes. Our scheme performed significantly better by increasing the number of nodes.

Graph in Figure 6-5 show the energy efficient cluster formation (b) effects for 20 numbers of rounds.

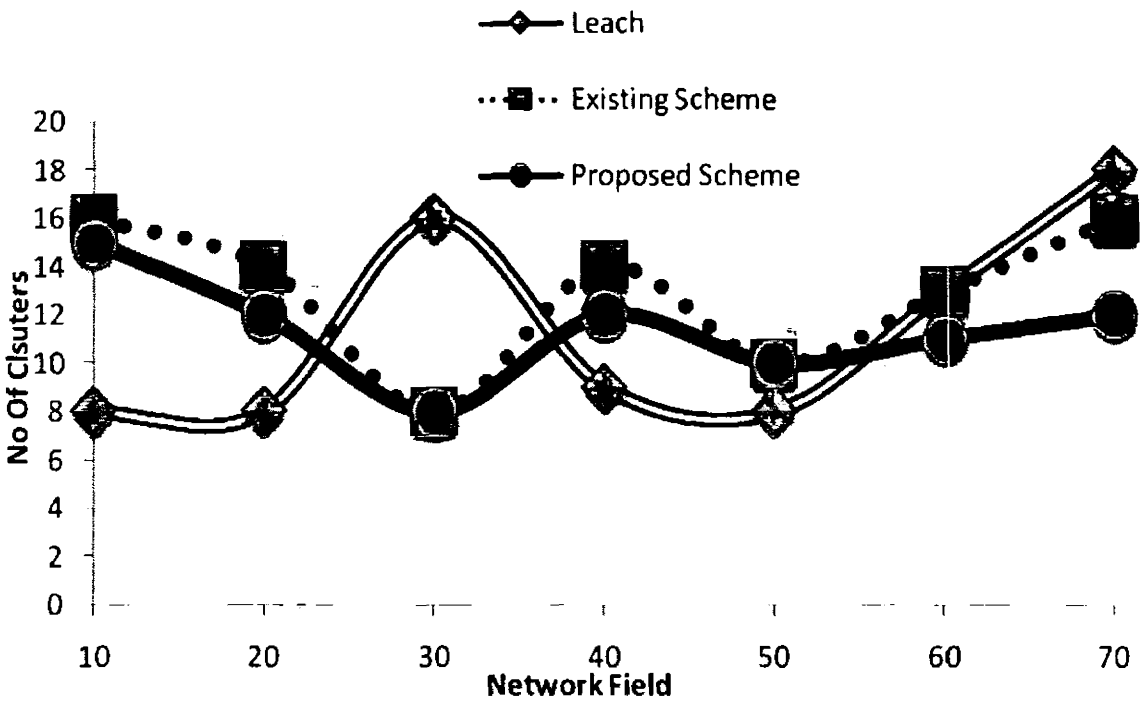

Figure 6-5: Energy efficient cluster formation (b)

The objective of this experiment was to measure effect of network area over number of clusters. At first we experimented with 10*10 m^2 network area while all parameters were kept constant. After this experiment we concluded that LEACH produces less number of clusters. Existing scheme produced greater number of clusters compared to LEACH. Our proposed scheme firstly produces higher number of clusters however upon gradual increase in the network area it produced fewer numbers of clusters compared to the both schemes.

After completing this experiment up to 70*70 network areas we argue that by the increasing of network area our schemes produces less number of clusters.

7

CONCLUSIONS & FUTURE WORK

7.1 CONCLUSIONS

In this research we proposed an energy efficient multihop clustering scheme for wireless sensor networks. Our proposed scheme recommends an improvement over existing scheme. Due to larger in distance from each other cluster heads drain their energy at an earlier. In our solution we used gateway nodes for communication with adjacent cluster head instead of using direct routing. This provides an efficient way for communication between neighbor cluster heads. This scheme is very successful if a number of candidate neighborhoods nodes are available for gateway selection. Our proposed scheme is highly energy efficient and scalable in all aspects. The simulation results prove that energy consumption in nodes and energy depletion in cluster head is extremely reduced and thus ending up with increased network life time.

7.2 Future work

In future we intend to develop a method for reducing of heavy load on gateway nodes. Simulation of this scheme will be performed in NS (Network simulator) for efficient results.

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