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ENERGY EFFICIENT RADIO ACCESS TECHNOLOGIES AND NETWORKING WIRELESS ACCESS NETWORK

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Abstract

LEACH (Low Energy Adaptive Clustering Hierarchy) is the first network protocol that uses hierarchical routing for Wireless Sensor Networks (WSN) to increase the life time of network. Research on WSN has recently received much attention as they offer an advantage of monitoring various kinds of environment by sensing physical phenomenon, such as in-hospitable terrain, it is expected that suddenly active to gather the required data for some times when something is detected, and then remaining largely inactive for long periods of time. So, efficient energy saving schemes and corresponding algorithms must be developed and designed in order to provide reasonable energy consumption and to improve the network lifetime for WSN. WSN are networks consist of large number of tiny battery powered sensor nodes having limited on-board storage, processing, and radio capabilities. Nodes sense and send their reports toward a processing center which is called sink node or Base Station (BS). Since the transmission and reception process consumes lots of energy for data dispensation, it is necessary to designing protocols and applications for such networks has to be energy aware in order to prolong the lifetime of the network. The proposed, LEACH-PR (Low Energy Adaptive Clustering Hierarchy - Power Resourceful) protocol includes clustering, routing and radio propagation technique by balancing the energy consumption of sensor nodes to improve the efficiency of data transmission and prolonging the network lifetime. The goals of this scheme are, increase the stability period of network, and minimize the energy consumption. The performance analysis of proposed LEACH-PR is compared with I-LEACH (Improved LEACH), EHE-LEACH (Enhanced Heterogeneous LEACH), and EEM-LEACH (Energy Efficient Multi-hop LEACH) protocols and concluded that, the LEACH-PR has significant improvement over in terms of lifetime of network, both in homogeneous and heterogeneous environments.

Keywords:

LEACH, Network Lifetime, Wireless Sensor Networks, Radio Capabilities

1. INTRODUCTION

Wireless Sensor Network (WSN) is a self-organized sensors network deployed randomly in monitoring through wireless communication. In WSN routing is the primary task for data communication between CH to BS. The routing algorithm used should be energy efficient so that it can surmount related power constraints. Although LEACH protocol prolongs the network lifetime in contrast to plane multi-hop routing and static routing, it still has problems such as LEACH is not applicable to networks that are deployed in large region as it uses single-hop routing where each node can transmit directly to the CH and the sink or BS.

The CHs used in the LEACH will consume a large amount of energy if they are located farther away from the sink. LEACH uses dynamic clustering which results in extra overhead such as the head changes, advertisement that increase the energy consumption. There is no separate categorize propagation models for different environment, to minimize path loss, which was the main weakness identified form the literature review.

The main objective of the thesis is to develop new approaches for providing energy efficiency, longer lifetime, quick data delivery for WSNs which are mainly used for those areas, where nodes remaining largely inactive for long periods of time. This thesis studies the performances of some existing algorithms and proposes an efficient algorithm for fulfilling the objective.

The proposed protocol is aimed at prolonging the lifetime of the sensor networks by balancing the energy consumption of the nodes. It makes the high residual energy node to become a CH. The proposed algorithm is compared with some of the existing LEACH protocols to assess the performance.

The following steps can be taken to save energy caused by communication in WSN.

- To schedule the state of the nodes (i.e. transmitting, receiving, idle or sleep).
- Using efficient routing and data collecting methods.
- Avoiding the handling of unwanted data as in the case of overhearing.

2. LITERATURE REVIEW

The first hierarchal protocol is the Low Energy Adaptive Clustering Hierarchal (LEACH). The idea of LEACH is to form cluster of sensor nodes based on received signal strength and use cluster head as the router to sink. Many hierarchical protocols were emerged based on the idea of LEACH. The goal of this chapter is to provide a current survey on LEACH based protocols.

2.1 EFFICIENT DISTRIBUTED ENERGY EFFICIENT CLUSTERING (EDEEC)

Energy–aware algorithm fit for multilevel heterogeneous WSN. In this algorithm CH are elected in which the ratio of the average energy of the network and nodes residual energy will be considered. Selection of CH is based on initial and residual energy level of nodes. The authors assumed that all the nodes of the sensor network contain different amount of energy, which is a source of heterogeneity. DEEC assure that all the nodes in the network die almost at the same time. DEEC protocol is centralized, as BS broadcast the total energy and estimate life time of all nodes. At the start of processing nodes should have kept the prior knowledge of total energy and lifetime of the network.

Simulation shows that DEEC perform more efficiently than other protocols (LEACH, SEP, LEACH-F) [6].

In order to achieve the design goal, the key tasks performed by Leach are as follows:

- Randomized rotation of the CHs and the corresponding clusters.
- Global communication reduction by the local compression.
- Localized co-ordination and control for cluster setup and operation.
- Low energy media access control.
- Application specific data processing.
- Energy Efficient Heterogeneous Clustered (EEHC) Scheme for WSNs

Kumar et al. [20] proposed an energy efficient three-level heterogeneous clustered scheme based on weighted probabilities for the election of CHs. EEHC protocol compares it's performance with LEACH in presence of heterogeneity. EECH has three types of nodes, super node, advance node, and normal node. Different nodes are having different weighted probabilities. The probability of threshold is obtained that is used to elect the CHs in each round. EECH takes full advantage of heterogeneity by introducing extra energy of advance and super node therefore increases the stable region and decreasing the unstable region when comparing to previous LEACH protocols [16].

2.2 ENERGY EFFICIENT UNEQUAL CLUSTERING (EEUC)

An energy-efficient unequal clustering mechanism for wireless sensor networks. EEUC is designed for periodic data gathering applications in WSN. According to this scheme the nodes in one region compete to become CH in such a way that the node's competition range decreases as it's distance to the base station decreasing. Thus the nodes closer to the BS consume less energy for intra cluster routing and can utilize it for inter-cluster routing. Energy consumed by cluster heads per round in EEUC much lower than that of LEACH standard but similar to HEED protocol.

2.3 ENHANCED HETEROGENEOUS LEACH (EHE-LEACH)

An enhanced heterogeneous LEACH protocol for lifetime enhancement of SNs (Sensor Node) and also overcome the major drawback of Stable Election protocol (SEP). There are two levels of node: normal and advance node. CH are selected on the bases of weighted probabilities, based on these weighted probabilities respective threshold.

An enhanced two-level heterogeneous LEACH (EHE-LEACH) protocol for lifetime enhancement of SNs and also overcome the major drawback of SEP protocol (i.e. poor stability). There are two levels of node: normal and advance node. Cluster heads are selected on the bases of weighted probabilities. Based on these weighted probabilities respective threshold is suggested. This protocol is using the combination of Direct Diffusion (DD) and LEACH. In EHE-LEACH fixed distance threshold is used to separate DD and clustering. The proposed model considers two parameters: minimize the execution and maximize the life time and stability by using combination of two techniques simultaneously direct diffusion and clustering.

The Half node alive and last node alive is the two key parameters used for the measurement of lifetime and stability of the system. Simulation results show that the lifetime and stability of network field is significantly enhanced as compared to LEACH and SEP.

2.4 ENERGY EFFICIENT MULTI-HOP LEACH (EEM-LEACH)

The energy efficient homogeneous routing protocol EEM-LEACH by Antoo et al. [7] that discovers a multi-hop path with minimum communication cost from each node to BS. CH selection is based on maximum residual energy and average energy consumption of nodes. The cluster head is chosen such that it has minimum energy consumption and maximum residual energy as average energy consumption is considered for CH selection. The CH discovers a multi-hop path to the base station. As CH is used to find the multi-hop path for data transmission thus need for global knowledge is abolished. The communication cost per packet gets reduced because of multi-hop communication which improves the network lifetime. In the proposed protocol the threshold $T(n)$ is adjusted by incorporating residual energy and average energy consumed. EEM–LEACH includes a multi-hop inter-cluster communication and direct communication. Multi-hop path from each CH to BS depends upon communication cost metric and is chosen in set-up phase [13].

This protocol is centralized i.e. BS at the center sends message. EEM-LEACH shows better lifetime, minimized energy consumption and good packet delivery than existing protocols.

2.5 HETEROGENEOUS MULTI-HOP LEACH ROUTING PROTOCOLS

Introduced a heterogeneous multilevel clustering approach to increase the energy efficiency by keeping the radio communication distance as minimum as possible [18]. There are three types of nodes: normal node, intermediate node and advance node. It allows inter-cluster communication. In this protocol cluster-head sends the aggregated data to an advance node which is closer to the BS or to BS directly depending upon the smaller distance. The protocol provides better results and is more energy-efficient as compared to LEACH [5].

2.6 IMPROVED–LEACH (I-LEACH)

An improved I-LEACH a homogeneous wireless sensor network to overcome two shortcoming of LEACH protocol i.e. CH selection is based on probability and location of CH is not certain which result CHs to be concentrated in one part of network is proposed by Kumar et al. [20], I-LEACH include two main changes, residual energy is used to select the CH instead of probability and coordinates are used to form cluster so that their must remain a CH close to every sensor node. I-LEACH also uses first order energy dissipation radio model. Simulation result shows that I-LEACH solves the issue of node heterogeneity as it works on the residual energy concept. I-LEACH improves the network lifespan over LEACH protocol.

An improved routing algorithm based on LEACH, known as ILEACH, is proposed in this paper. Firstly, the I-LEACH employed the residual energy to form clustering, which can avoid the low energy node becoming a cluster head. Secondly, an energy function is proposed to balance the energy consumption among cluster heads. Finally, a data aggregation tree is constructed to transmit the data from the cluster heads to sink node. WSNs consists sensors which communicate to sensors by multi-hop.

Generally, research is continuing on sensor network through two stages, at the beginning stage is primarily intended for node and the last stage is for network-level issues. The main research works in this stage involve the network layer and MAC layer protocol based on energy optimization, node localization technology, clock synchronization technology and data fusion technology. As the power of the sensor node cannot be increased then how the nodes can be efficiently use in the network so that system energy becomes the prime factor for designing routing protocol. In this paper, we proposed a new energy model in our protocol and compare several aspects with existing LEACH protocol.

2.7 VICE-CLUSTER (V-LEACH) PROTOCOL

A new version of LEACH protocol called improved V-LEACH which increase network life time by selecting vice- CH by Jia et al. [17], Vice CH is alternate head that work only when the CH will die. The process of vice-CH selection is based on minimum distance, maximum residual energy and minimum energy. Conclusion shows that the new version of improved V-LEACH outperforms the original LEACH protocol by increasing the life time of network.

2.8 CENTRALIZED-LEACH (LEACH-C)

Centralized LEACH has steady-state same as basic LEACH protocol but varies in set-up phase. The CH nodes are chosen by BS. Each node sends its current location and energy level to the BS and the BS uses this global knowledge via GPS or other tracking methods to produce better clusters require less transmission energy. The BS will choose only those nodes to become CH nodes which have enough energy level and broadcast this information to all nodes in the network. Advantage of this protocol over basic LEACH is the deterministic approach of choosing number of CH nodes in each round which is predetermined at the time of deployment. LEACH-C causes better distribution of CH nodes in the network. But LEACH-C requires current location information of all nodes using GPS which is not robust.

2.9 ENERGY-LEACH (LEACH-E)

In LEACH-E protocol, initially all nodes have same energy and same probability of becoming the CH. After the first round, energy level of each node changes. Then the amount of residual energy of each node is used to select CH nodes. The nodes with highest residual energy are preferred on rest of the nodes. LEACH-E enhance lifetime of network by balancing energy load among all nodes in the network by Kumar et al. [20] as shown in Fig.1.

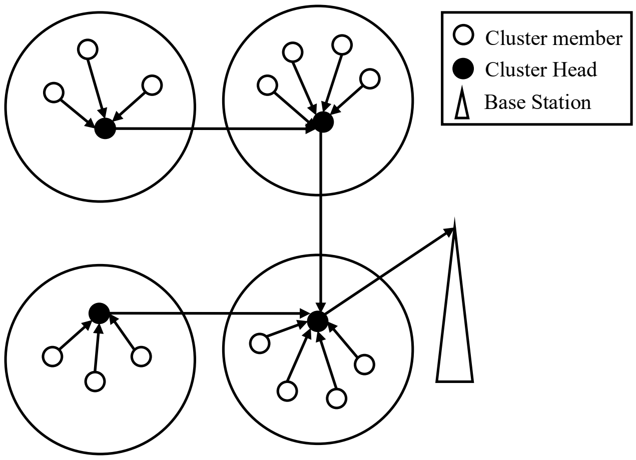

Fig.1. LEACH-E Protocol

2.10 ADVANCED-LEACH (LEACH-A)

LEACH protocol has a problem that the CH node consumes more energy than normal nodes [12]. Advanced-LEACH protocol, a heterogeneous protocol used to decrease probability of failure nodes and for extending the time interval before the death of the first node (called stability period) [8]. In Fig.2 each sensor knows the starting of each round using synchronized clock. Let *n* be the total number of nodes and m be the fraction of *n* that have energy more than other nodes called CGA nodes (nodes selected as gateways or CHs). The rest of $(1-m)n$ nodes act as normal nodes [15].

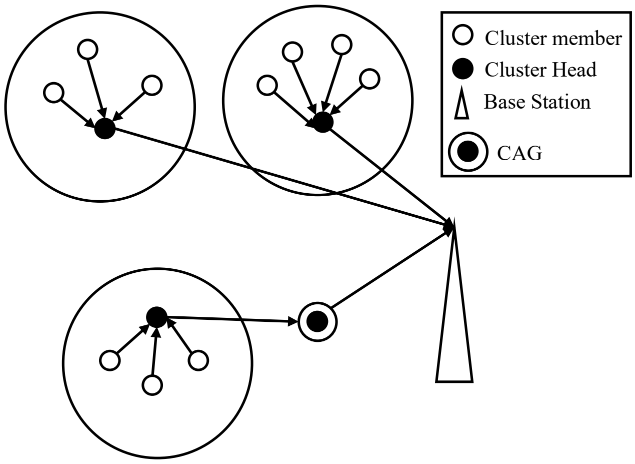

Fig.2. LEACH-A Protocol

2.11 SURVEY OF ROUTING IN WSN

In this session, the literature surveys conducted on different types of routing methodologies in WSN are presented.

2.11.1 Cluster Based Hierarchical Routing Protocol:

Akyildiz et al. [4] proposed the normal nodes called cluster members join the corresponding CH nodes on the basis of principle of proximity. Normal nodes sense data and send directly to the CH nodes. The CH nodes receive sensed data, aggregate the data to remove redundancy and fusion processes are carried out and data is send to the sink. LEACH proposed typical hierarchical clustering routing protocol by Depedri et al. [14], which adopts distributed clustering algorithm where CH rotation mechanism, data aggregation, and data fusion technologies effectively improves the lifetime of network. In order to optimize energy in the network, nodes are selected as CH circularly and randomly.

2.11.2 PEGASIS Routing Protocol:

Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol [10] is an improved version of LEACH protocol. Instead of forming clusters, it is based on forming chains of sensor nodes. One node is responsible for routing the aggregated data to the BS. Each node aggregates the collected data with its own data and then passes the aggregated data to the next string. The difference from LEACH is to employ multi hop transmission and selecting only one node to transmit the data to the sink or BS. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data aggregation is employed, PEGASIS outperforms the LEACH.

The core conception in PEGASIS is to form a chain among all the sensor nodes so that each node can receive from and transmit to the closest neighbor. Gathered data moves from node to node, get fused, and eventually a designated node (cluster head) transmits to the BS. Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced. The method of Building a chain to minimize the total length is similar to the traveling salesman problem, which is known to be intractable. However, with the radio communication energy parameter, a simple chain built with a greedy approach performs quite well. However excessive delay is introduced for distant nodes, especially for large networks, where single leader can be a bottleneck.

2.11.3 TEEN Routing Protocol:

Manjeshwar and Agarwal [2] proposed the Threshold Sensitive Energy Efficient sensor Network Protocol (TEEN) protocol. Closer nodes form clusters, with CHs to transmit the collected data to one upper layer. Forming the clusters, CHs broadcast two threshold values. First one is hard threshold; it is minimum possible value of an attribute to trigger a sensor node. Hard threshold allows the nodes to transmit the event, if the event occurs in the range of interest. Therefore, a significant reduction of the transmission delay occurs. Unless a change of minimum soft threshold occurs, the nodes don't send a new packet of data. Employing soft threshold prevents from the redundant data transmission. Since the protocol is to be responsive to the sudden changes in the sensed attribute, it is suitable for time-critical applications.

TEEN protocol is used for precipitous changes in the sensed attributes in the network. It uses a data centric mechanism and makes clusters in a hierarchical fashion. Two threshold values are broadcast to the nodes: hard threshold and soft threshold etc. The hard threshold is the minimum possible value of an attribute. Sensor nodes send data to the cluster head only if they found the sensed value is greater than the hard threshold. If sensor nodes found that the sensed value is less than the attribute value of threshold than they do not send the data to the cluster head. Thus, relative data is send by the sensor nodes.

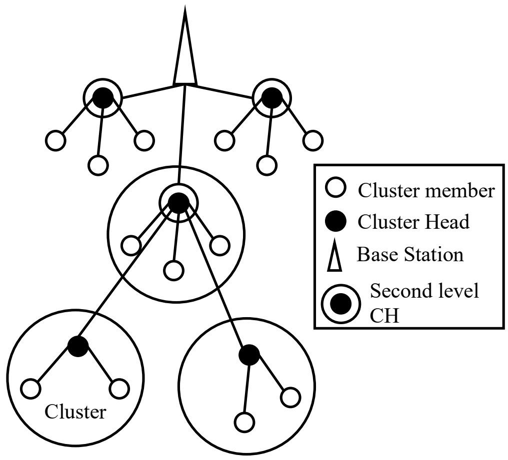

Fig.3. Clustering Topology of TEEN

Next time when sensor node again sense value greater than the hard threshold value than they check the difference between current and earlier value with soft threshold as shown in Fig.3. If the difference is again greater than the soft threshold than the sensor nodes will send recent sensed data to the cluster head. This process will remove burden from the cluster head.

2.12 SURVEY ON RADIO PROPAGATION

In this session, the literature surveys conducted on different types of radio wave propagation in different terrains are discussed.

2.12.1 Basic Mechanisms of Electromagnetic Wave Propagation:

During propagation between the transmitting and the receiving antenna, radio waves interact with environment, causing path loss. Path loss is defined as the difference between the transmitted and the received power. Propagation in Free Space Path Loss (FSL) by Borko et al. [3] says the distance between transmitting and receiving antennas given in kilometers and is frequency in MHz. The free space loss increases by 6 dB for each doubling in either frequency or distance (or 20 dB per decade). In point-to-point communications the Free Space Loss (FSL) model can be used only when there exists a direct ray between the transmitting and the receiving antenna by Kiran and Vishal [19].

The point-to-surface type communications, even in LOS (line-of-sight) conditions, reflected and diffracted rays reach the receiving antenna together with a direct ray thus increasing calculation complexity. The loss between two antennas can be less than it's free space value only in highly anomalous propagation conditions. An example of such exception is when propagation is confined to some guided structure, such as street canyons.

2.12.2 Radio Wave Propagation in Built-Up Areas:

During propagation in built-up areas electromagnetic waves interact with environment (trees, buildings, hills etc.) what causes path loss. Different types of environment will cause a different attenuation level. In practice, because of better propagation conditions, it is possible that a system with less demanding parameters offers a better coverage area than a system with more demanding parameters [19]. It is very important to classify terrain as accurately as possible since propagation model selection as well as propagation model complexity strongly depend on environment.

2.12.3 Radio Propagation Models:

Radio propagation models are empirical mathematical procedure for the depiction of radio wave propagation as a “function of distance, frequency or any specific conditions” radio waves help in communication of a wireless network, both in short and long range which is based on radio transmission. The geographical environment (mountains, water area, plains and hills) or propagation environment along with physical parameters of the medium like temperature, pressure, terrains, humidity, and environmental noise affects the radio wave propagation. PL happens when electromagnetic waves interact with environment when transmitted between the signal undergoes reflection, diffraction, scattering and absorption before hitting the receiver [11]. This is because; the signal transmission channel includes buildings, obstacles, trees, foliage, vegetation and moist air. This reduces the amplitude and phase of the signal.

3. VARIOUS PATH LOSS MODELS

3.1 FREE SPACE PATH LOSS (FSPL)

The signal loss that happens between the transmitter and the receiver in free space with Line of Sight condition is termed as free space path loss or generally abbreviated as FSPL. Free space path loss is calculated based on distance between the transmitter and receiver, signal wavelength (λ) expressed in meters. Transmitter gain, receiver gain, transmitter and receiver losses, transmitted power, obstacles in path, etc., are excluded in calculation. Free space loss holds good in idealistic conditions assuming the transmitter antenna to be isotropic. The log formula for free space path loss in Eq.(1).

$$FSPL(\text{dB}) = 2\log_{10}(d) + 20\log_{10}(f) + 32.44 \tag{1}$$

3.2 PATH LOSS MODEL

Path loss is defined as the difference between transmitted and received power represented in decibels (dB). Path loss increases as the distance between the mobile station (MS) and base station (BS) increases and is highly influenced by terrain environment. The signal hits the receiver after crossing a multipath with high attenuation on the RF signal. This is explained by Eq.(2).

$$P_r = (d)\, P_t\, G_t\, G_r \lambda^2 / (4\pi)^2 d^2 L \tag{2}$$

In general, path loss is defined as decrease in signal amplitude caused due to the following factors and Eq.(2) shows the path loss.

- Absorption losses
- Multipath
- Diffraction
- Free space loss
- Vegetation and building obstacles
- Terrain

3.3 OKUMURA HATA

Okumura-Hata Model or Hata model is developed based on path loss data collected from Okumura model. This model is easy to apply in real time conditions and can be extended to different terrains with correction factors. This model can be applied to macro cellular environment and exploited more in lower frequencies as shown in Eq.(3) to Eq.(8).

3.3.1 Urban Areas:

$$L_{50}(\text{dB}) = 69.55+26.16\log(f_c)-13.82\log(h_t)-a(h_r) + [44.9–6.55\log(h_t)] \log(d) \tag{3}$$

where, f_c is the operating frequency between 150MHz to 1500MHz. h_t is the height of the transmitting antenna; range 30 meters to 200 meters. d is the distance between the transmitter and receiver in km and $a(h_r)$ is the mobile antenna or CPE or mobile station height correction factor.

For urban/dense urban/core urban or large cities

$$a(h_r) = 8.29(\log(1.54h_r))^2-1.1, \text{ for } f_c \leq 200 \text{ MHz} \tag{4}$$

$$a(h_r) = 3.2(\log(11.75h_r))^2-4.97, \text{ for } f_c \leq 400 \text{ MHz} \tag{5}$$

In suburban and residential areas h_r is in the range of 1-10 m.

$$a(h_r) = (1.1\log(f_c)-0.7)h_r - (1.56\log(f_c)-0.8) \tag{6}$$

Path loss for suburban and residential areas;

$$L_{50}(\text{dB}) = L_{50}(\text{urban}) - 4.78 (\log(f_c))^2 + 18.33\log (f_c)-40.94 \tag{7}$$

Path loss for Open/Rural areas

$$L_{50}(\text{dB}) = L_{50} (\text{rural}) – 2(\log (f_c/28))^2 - 5.4 \tag{8}$$

Okumura Hata model can also be applied to irregular terrain, due to the additions of parametric corrections factors, which is not available in the basic model.

3.4 MULTIPATH PROPAGATION

Wide band channels are used in WiMAX for wider bandwidth to support high data rates. The signal as it passes from the transmitter to reach the receiver, undergoes a series of path and finally reaches the destination. If a radio signal takes more than one path to reach the receiver, it is called multipath propagation. Multipath propagation is common in wireless and mobile environment, since the radio signal travels through an unguided wave medium i.e. air medium between the transmitter and receiver. The effects of multipath propagation on wide band channels make the symbols to spread to the next adjacent symbol resulting in inter symbol interference. WiMAX uses a modulation technique called OFDM, which helps to mitigate ISI, caused due to multipath propagation in NLOS environments. OFDM makes “the symbol duration of the subcarriers is increased in relation to the delay spread”. Environmental factors, refraction and reflection caused by ionosphere, atmosphere duct, water bodies, obstacles such as buildings and mountains cause the signal to fade in the propagating media. Fading happens due to multipath propagation. The propagation channel is part of mobile radio system between the transmitter and the receiver. The influence of multipath propagation on the transmitted signal causes the receiver to receive multiple copies of the same transmitted signal. At the receiver the multiple copies of the transmitted signal are added with different phases thereby increasing bit error rate and making the single power poor for detection at the receiver [9]. In digital radio communications, multipath causes inter symbol interference (ISI). ISI caused due multipath propagation reduces the quality of communications in digital radio and making the signal to blur over long distance. This introduces errors on the transmitted signal and thereby increasing the BER.

In mobile communications, the receiver can move close or away from the transmitter antenna causing a "change in frequency of a wave". This phenomenon is termed as Doppler Shift. Fading in mobile environment may be categorized into four types namely;

- Fast fading
- Slow fading
- Flat fading
- Frequency selective fading

4. IMPLEMENTATION METHODOLOGY

Energy efficient protocols that utilize clustering are found to be more scalable. In previous chapter, we have reviewed various clustering based energy efficient schemes in WSN. As each node depends on energy for it's activities, it is necessary to improve network lifetime of WSN by effectively reducing energy consumption. To achieve this objective many routing algorithms have been proposed. Among all the proposed methods, hierarchical routing protocols greatly satisfy the limitations and constraints in WSNs. It is mainly considered as a two-layer architecture where one layer is engaged in cluster head selection and the other layer is responsible for routing. The proposed LEACH–PR protocol delivers improved performance by energy efficient and increasing level in lifetime of the WSN by implementing FEDC for clustering and Robust Aware Sleep Scheduling Routing (RASSR) protocol for inter-cluster communication and Radio Propagation technique called Multi-Ray Radio Propagation (MRRP) for intra-cluster communication between CH and BS. This chapter includes detail study of FEDC methodology and next chapter includes about RASSR and MRRP.

4.1 ARCHITECTURAL DESIGN OF LEACH-PR

The design flow of LEACH-PR represents the data transfer between the transmitter and the receiver. Transmission or receiving process begins with clustering based on two parameters, residual energy and inter-cluster communication cost. The node with maximum energy level is selected as CH and remaining SN are linked to CH based on inter-cluster communication cost to form cluster.

Then routing initiate either through direct communication or communication via CH. The direct communication is process of data transfer between CH and the BS for long distance communication.

4.2 FEDC

FEDC is a hierarchical, distributed, clustering scheme in which a single-hop communication pattern is retained within each cluster, whereas multi-hop communication is allowed among CHs and the BS.

4.3 FEDC FLOW CHART

The formation of clusters in sensor networks highly depends on the time taken to receive the neighbor node message and the residual energy. The protocol is divided into rounds, and each round is triggered to find out the optimal CH. The proposed FEDC clustering involves following steps. The clusters are formed based on the following,

Step 1: *Neighbor information retrieval* - The neighbor node information is sensed by broadcasting the beacon messages throughout the network.

Step 2: *Perform sorting* - The sorting is performed to retrieve the list of all neighbor nodes about it's hop distance.

Step 3: Calculate the residual energy of neighbor nodes. Finally, the sorting algorithm is executed based on the residual energy of the neighbor nodes.

Step 4: *Selection of CH* - Analyze all the members of cluster one-by-one and crown the node with high residual energy as a CH.

Step 5: *Data aggregation based on data ensemble* - After gathering the data from different nodes, the CHs need to forward the data to the BS. Hence, the forwarding nodes are selected based on the highest residual energy among the nodes. The nodes which are having the highest energy are selected as a CH to forward the data to the BS.

4.4 PROBLEM FORMULATION – FEDC

The proposed energy-efficient protocol is FEDC. FEDC is a hierarchical, distributed, clustering scheme in which a single-hop communication pattern is retained within each cluster, whereas multi-hop communication is allowed among CHs and the BS. The CH nodes are chosen based on two basic parameters, residual energy and intra-cluster communication cost.

Starting of a round, BS broadcasts HELLO packets among the sensors periodically. If the RSSI (Receiving Signal Strength Indicator) of the received signal is greater than clustering threshold, then no need to form clusters. Based on stronger RSSI nodes closer to the BS are selected to send their data directly to BS. This region is called direct communication region. Rests of the nodes follow dynamic clustering technique.

Residual energy of each node is used to probabilistically choose the initial set of CHs. On the other hand, inter-cluster communication cost reflects the node degree or node's proximity to the neighbor and is used by the nodes in deciding to join a cluster or not. Thus, unlike LEACH, in FEDC the CH nodes are not selected randomly. Only sensors that have a high residual energy are expected to become CH nodes. Also, the probability of two nodes within the transmission range of each other becoming CHs is small.

Moreover, when choosing a cluster, a node will communicate with the CH that yields the lowest inter-cluster communication cost. In FEDC, each node is mapped to exactly one cluster and can directly communicate with its CH. Also, energy consumption is not assumed to be uniform for all the nodes. The algorithm is divided into three stages. At the beginning, the algorithm sets an initial percentage of CHs among all sensors. This percentage value, C_{prob}, is used to limit the initial CHs announcements to the other sensors. Each sensor sets it's probability of becoming a CH, CH_{prob}, as follows Eq.(9).

$$CH_{prob} = C_{prob} \times E_{residual} / E_{max} \tag{9}$$

where, $E_{residual}$ is the current energy in the sensor, and E_{max} is the maximum energy, which corresponds to a fully charged battery.

CH_{prob} is not allowed to fall below a certain threshold p_{min}, which is selected to be inversely proportional to E_{max}.

The main body of the algorithm consists of a (constant) number of iterations. Every sensor goes through these iterations until it finds the CH that it can transmit to with the least transmission power (cost). If it hears from no CH, the sensor elects itself to be a CH and then sends an announcement message to its neighbors informing them about the change of status. Finally, each sensor doubles its CH_{prob} value and goes to the next iteration of this phase. It stops executing this phase when its CH_{prob} reaches 1. Therefore, there are two types of CH status that a sensor could announce to its neighbors:

- The sensor becomes a 'tentative' CH if its CH_{prob} is less than 1 (it can change its status to a regular node at a later iteration if it finds a lower cost CH).
- The sensor permanently becomes a CH if its CH_{prob} has reached 1.

At the end, each sensor makes a final decision on its status. It either picks the least cost CH or announces itself as CH. Note also that for a given sensor's transmission range, the probability of CH selection can be adjusted to ensure inter-CH connectivity. Generally, FEDC mechanism to select the CHs and form the clusters. They produce a uniform distribution of CHs across the network through localized communications with little overhead. It also clearly outperforms LEACH with regard to the network lifetime and the desired distribution of energy consumption.

However, synchronization is required and the energy consumed during data transmission for far away CHs is significant, especially in large-scale networks. Also, knowledge of the entire network is normally needed to determine reliably the intra-cluster communication cost and configuration of those parameters might be difficult in practical world.

5. RASSR

Efficiently use the residual energy of each sensor node the proposed algorithm has proper distribution of the network load among the clusters, which ensures the maximum stability and lifetime of the WSNs.

5.1 NETWORK MODEL

The proposed protocol following network assumptions are considered: All nodes are stationary once deployed randomly in the field and they are left unattended after deployment. For simplicity and convenience, the sensing mode is Boolean mode. All nodes should be roughly time synchronized on the order of seconds. Nodes are location-unaware, i.e. not equipped with GPS-capable antennae. There is single BS located in the center of the field. The BS is a stationary, high-energy node, position of the BS is fixed. Each sensor node periodically senses the monitored environment, and has a perpetual desire to send the sensed data to the BS. Sensor nodes are probed with power control capabilities to change their transmitted power. Radio transmission in all directions has the same amount of energy consumption. The nodes are considered to die only when their energy is exhausted.

5.2 RASSR PROTOCOL

The proposed scheme RASSR algorithm for data transmission can be divided into direct communication and transmission via CH. *Direct communication*: Nodes in this zone send their data directly to base station. Nodes sense environment, gathers data or information and send it directly to BS. *Transmission via CH*: Nodes in this zone transmit data to BS through clustering. CH is selected among nodes and organizes themselves into small groups known as clusters. Then CH collect data from member nodes aggregate it and transmit it to BS. CH selection is most important. But before performing cluster formation we introduce sleep-awake policy for the sensors.

5.3 NODE PAIRING

Before performing routing, a node has to select its nearest node. A node sends a request message Find_Nearest_Neighbour. The 1-hop neighbor nodes which are closer to that node send a reply with their distances from that particular node and they are included in Eligible_Neighbour_List. Then the node in the Eligible_Neighbour_List which has maximum RSSI range of the received signal is selected as next node. The two nodes are added as coupled and then Node_Paired_ID message is broadcast in the network. Algorithm presents the mechanism of node pairing.

After performing the node pairing mechanism each node checks its remaining energy with its paired neighbor. In a pair, a node switches into Active mode if its residual energy is greater than its paired node. Thus node having more residual energy in a pair will participate in clustering technique and the other one will remain in Sleep mode for that round. During a sleeping period, the node ceases to perform any communication with the environment. Thus power consumption is assumed to be minimal, whereas when a sensor is awake, it consumes regular amount of energy. In next communication interval, nodes in Active-mode switch into Sleep-mode and Sleep-mode nodes switch into Active mode if and only if Sleep-mode node's residual energy is above Active-mode node's energy level. In this way, we are able to minimize energy consumption because nodes in Sleep-modes save their energy by not communicating with the CHs. Nodes in Sleep-mode also save their energy by avoiding overhearing and idle listening during sleep-mode. If coupled partner of a node is dead, then it will become active for rest of the round. Isolated nodes remain in Active-mode for every round till their energy resources depleted. In algorithm we describe step by step procedure of node mode set up.

5.4 DATA TRANSMISSION AND DATA AGGREGATION

The active-mode nodes transmit the sensed data to CH at the time of TDMA slots. Sleep-mode nodes do not participate and save energy. The selected CHs broadcasts its CH message. Non-CH active nodes, sends joining request message to CH from which it received the highest RSSI. CH accepts the joining request and forms respective clusters. Then CHs aggregate received data from each node and transmit to BS. Data aggregation may be considered to be an effective technique to compress the amount of data sent to BS. Due to data aggregation technique a noticeable amount of energy is saved. If there are N total number of nodes and X are the optimal number of CHs then the average number of nodes in each cluster will be evaluate in Eq.(10).

$$(N/X)\text{-}1 \tag{10}$$

In order to transmit data, the ratio of a non-CH node dissipates E_{TX} to run the transmitter circuitry and E_{amp} for transmit amplifier to achieve acceptable SNR (Signal-to-Noise Ratio). So, for transmission of k_c bit message a non-CH node expands following the first order radio model

$$E_{non\text{-}CH} = ((N/X)\text{-}1)(E_{TX}\times k_c + E_{amp}\times k_c\, d_{toCH}^2) \tag{11}$$

where, d_{toCH}^2 is the distance between nodes and CHs.

To receive data from non-CH node by the radio of CH in each cluster expands:

$$E_{receive} = (E_{RX}\times k_c)((N/X)\text{-}1) \tag{12}$$

where, E_{RX} is energy dissipated by receiver circuitry for receiving data. Energy dissipated by CH to aggregate data received from its associated nodes.

$$E_{AGR} = (E_{DA}\times k_c)(N/X) \tag{13}$$

Transmission energy E_T dissipated by SN to transmit aggregated data packet transfer ration to the CH is:

$$E_T = (E_{TX}\times k_A + E_{amp}\times k_A\times d_{toCH}^2) \tag{14}$$

where, k_A is aggregated data and d_{toCH}^2 is the distance between CH and BS. Total energy dissipated by CH in a round is:

$$E_{CH} = E_{receive} + E_{AGR} + E_T \tag{15}$$

Total energy dissipated by CH is the energy dissipated in reception of data from its associated nodes shown in Eq.(11), aggregation of received data shown in Eq.(12) and Eq.(13) and transmission of that data to the BS shown in Eq.(14). After performing aggregation each SN sends concise data to the CH shown in Eq.(15).

5.5 NETWORK LIFE TIME

After every round of data transmission, CH receives the status of the current energy level from all sensor nodes in the network. Then selection of powerful nodes are done based on the received energy values. The CH computes the average energy level of the active nodes as follows in Eq.(16).

$$E_{avg} = \sum E_{resi}/m \tag{16}$$

where, m is the total number of active nodes($\leq N$), E_{resi} is nodes residual energy.

After CH broadcasts average energy of the network, node having remaining energy greater than or equal to the system average energy include themselves in the set of eligible further rounds. If a node finds its $E_{resi} \geq E_{avg}$ then it sends a request message to find eligible neighbors. The 1-hop neighbor nodes which are closer to that node send a reply with their Energy Consumption Rate E_{ecr} in previous round.

5.6 ENERGY CONSUMPTION

Energy consumption is easily one of the most fundamental but crucial factor determining the success of the deployment of sensors and WSNs due to many severe constraints such as the size of sensors, the unavailability of a power source and inaccessibility of the location and hence no further handling of sensor devices once they are deployed. Efforts have been made to minimize the energy consumption of WSN and lengthen their useful lifetime at different levels and approaches. Some approaches aim to minimize the energy consumption of sensor itself at its operating level, some aim at minimizing the energy spent in the input/output operations at data transmission levels, and others target the formulation of sensor networks in terms of their topology and related routing mechanisms. The generic goal here is to reduce the amount of energy consumption of some components of the application as much as possible by reducing the tasks that have to be performed by the sensors and the associated networks yet fulfills the goal of intended application.

The main problem with these approaches is that they may succeed in reducing the energy consumption in one component of the overall WSN application, but this gain is often negated by an increase in the energy consumed in other components of the application. There has been very little understanding of overall energy consumption map of the entire application, the major components of this energy map and the interplay among the components. We have approached the problem for a different angle by focusing of energy constituents of an entire sensor network application. An energy constituent represents a major energy-consuming entity that may be attributed to a group of functional tasks. Eventually, these tasks have to be mapped to energy consumed actions that have to be performed by sensors and other components such as sensors' antennas, transceivers and central processing units.

The node which has minimum energy consumption rate in previous round and with $E_{resi} \geq E_{avg}$ is selected as routing node, where energy consumption rate is as follows in Eq.(17)

$$E_{ecr} = E_0 - E_{resi} / (r\text{-}1) \tag{17}$$

where, E_0 is initial energy of node, E_{resi} is the residual energy of node and r is the current round.

5.6.1 Stable Region:

Most of the analytical results for LEACH-type schemes are obtained assuming that the nodes of the sensor network are equipped with the same amount of energy-this is the case of homogeneous sensor networks. In this paper we study the impact of heterogeneity in terms of node energy. We assume that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network. We are motivated by the fact that there are a lot of applications that would highly benefit from understanding the impact of such heterogeneity. One of these applications could be the re-energization of sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy. Note that due to practical/cost constraints it is not always possible to satisfy the constraints for optimal distribution between different types of nodes.

The stability period and network lifetime are used as key indicators to estimate performance of the proposed approach. The stability period shows that the time interval from the start of the operation to the first node dies. Here, the model of a WSN is shown with nodes heterogeneous in their initial amount of energy. We particularly present the setting, the energy model, and how the optimal number of clusters can be computed. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let m be the fraction of the total number of nodes n, which are equipped with times more energy than the others. The computation for average energy level or dead nodes as follows in Eq.(18).

$$E_{dead} = \sum m - N \quad (18)$$

where, m is number of alive nodes ($\leq N$), and N total number of nodes.

5.7 THROUGHPUTS

In this section we analyze the performance of networks with control in terms of network throughput and energy efficiency. We first state our assumptions and describe our traffic model. The proposed model analyze the performance of networks using LEACH-PR under different traffic patterns, network loads, link layer reliability and fundamental constraints. Much progress has been made towards understanding the network throughput. The performance limit of the network throughput is defined as the Maximum Stable Throughput (MST) of the network. The maximum stable throughput is the maximum amount of traffic per unit time (usually measured in bits/sec) that can be injected into the network from all the sources while the size of the queue at any network node is bounded. Usually, it is assumed that all nodes generate equal amount of network traffic. In this case, the maximum stable throughput per node can be similarly defined. In most of the literature on performance limits with respect to network throughput, the term capacity is used to refer to the maximum network throughput achievable. We will follow this convention in this chapter when it is appropriate.

The works reviewed in this section concentrate on the interference-constrained capacity of the network. The results on the energy-constrained capacity will be discussed in the next chapter, along with a comparison between interference-constrained capacity and energy-constrained capacity. The throughput can be determined as follows in Eq.(19)

$$R = I / T \text{ p/s (Packet per Second)} \quad (19)$$

where, R is the rate at which the process is delivering between the SN and the CH, I is the number of units contained within the system and T represents taken for all to deliver.

6. MULTI-RAY RADIO PROPAGATION MODEL (MRRP) FOR INTRA-CLUSTER COMMUNICATION

A single LoS (Line of Sight) path between to nodes in heterogeneous system is seldom the only means of propagation. The MRRP reflection model consider both the direct path and ground reflection path. This model was proposed as solution for WIMAX planning at 3.5GHz. This model can be used in a link distance range of 0.1km to 8km. The height of base station antenna can be from 10m to 80m, with the receiving antenna height of 2m to 10m. This model gives more accurate prediction at a long distance than the free space model.

6.1 FORMULATION OF MRRP MODEL

MRRP models introduce two new components, γ the path loss exponent, s- week fading standard deviation. Both components are random variables through statistical procedure. This model supported 3 major terrain types as shown in Table.1.

Table.1. MRRP model terrain description

MRRP Types	Terrain Description
Type A	Hilly terrain with heavy tree density
Type B	Hilly terrain with light tree density or flat terrain with moderate to heavy tree density
Type C	Light tree density

Path loss for MRRP model is given in Eq.(20)

$$PL_{MRRP} = A + 10\,\gamma \log(d/d_0) + X_f + X_h + s \quad (20)$$

for $d > d_0$

$$A = 20 \log(4\pi d_0/\lambda)$$

$$\gamma = a - bh_t + c/h_t$$

where, d is the distance between the transmitter and receiver (expressed in meters) and d_0 = 100 meters, X_f is the correction factor for frequencies above 2GHz, X_h is the correction factor for receiver antenna height, λ is the wavelength (expressed in meters), γ is the the path loss exponent, s is the shadowing factor for vegetation and obstacles in the propagation path, h_t is the height of the base station and a, b, c are constants as per Table.2

Table.2. MRRP model constants

Model Parameters	Type A (Hilly terrain with moderate to heavy tree density)	Type B (Hilly terrain with light tree density or flat terrain with moderate to heavy tree density)	Type C (Light tree density)
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

Mainly our proposed LEACH–PR explains the lowest path loss model MRRP and found to be reasonably accurate in predicting the large-scale signal strength over distances of several kilometers for wireless radio systems that use tall towers as well as for LoS microcell channels various terrain.

7. PERFORMANCE ANALYSIS AND DISCUSSION

The simulation with certain parameters like Number of Rounds, Energy level, Size of the message, Average energy consumption, and find number of dead nodes after completion of specific number of rounds etc. The simulation results of proposed algorithm LEACH-PR is discuss in detail by compared to show that LEACH-PR is better than other existing protocols like I-LEACH, EHE-LEACH, and EEM-LEACH.

7.1 SIMULATION SETTINGS

I simulate a clustered WSN in a field with dimensions 100×100m. The total number of sensors $n = 100$. The nodes, both normal and advanced, are randomly (uniformly) distributed over the field. This means that the horizontal and vertical coordinates of each sensor are randomly selected between 0 and the maximum value of the dimension. The sink is in the center and so, the maximum distance of any node from the sink is approximately 70m (i.e. $2\sqrt{(A/2)}$, where A is the length of the network area). Initial energy of a normal node is set to $E_0 = 0.5$ Joules, although this value is arbitrary for the purpose of this study, this does not affect the behavior of our protocol.

The radio characteristics used in our simulations are summarized in Table.3. The size of the message that nodes send to their CHs as well as the size of the (aggregate) message that a CH sends to the sink is set to 4000 bits. Total number of rounds considered is 5000. In our simulation environment the BS is located at the centre of the sensing field. MATLAB 7.5.0 is used for simulation.

Table.3. Parameters used in implementation of LEACH-PR

Parameters	Value
p	0.1
n	100
E_0	0.5J
E_{TX}	50nJ/bit
E_{RX}	50nJ/bit
Size of Message	4000 bits
r	5000

7.2 PERFORMANCE MEASURES

The following simulation metrics are evaluated for performance analysis of the algorithm. CHs selection at every round: This is the process of CHs selection at every round depends on residual energy. CHs collect information from associated non-CH nodes and aggregate them to make it compact and minimize redundancy.

- *Number of alive nodes per round*: Total number of nodes which are able to sense the environment. This instantaneous measure reflects the average energy of the network.
- *Network Lifetime*: The time interval between the start of the networks operations and end of the last alive node.

7.2.1 CH Selection per Round:

We can see that our protocol not only performs better than other three I-LEACH, EHE-LEACH and EEM-LEACH, but distribution of energy consumption is also uniform. As in each round LEACH-PR checks for system remaining energy and system average energy, so CH selection is done in a proper way by ensuring that CH has comparatively higher energy than rest of nodes.

The Fig.4 shows, simulated result is compared with I-LEACH, EHE-LEACH, EEM-LEACH with the proposed LEACH-PR and shows the difference in data transfer rate. But LEACH-PR significantly prolongs energy level even after 5000 rounds.

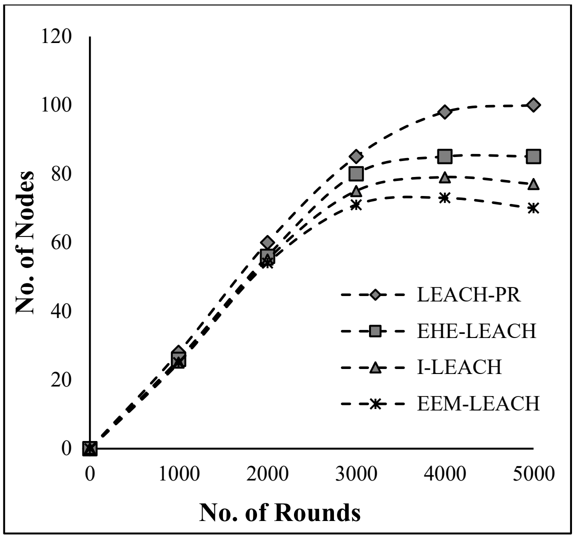

Fig.4. Comparison between I-LEACH, EHE-LEACH, EEM-LEACH, LEACH-PR presence of heterogeneity: No. of Nodes vs. Rounds (for 5000 Rounds)

7.2.2 Network Lifetime:

For simulations, the proposed system have considered three different parameter settings and each of m % advance nodes has factor of α times more energy.

- $m = 0.1$ and $\alpha = 1$ i.e. 10 percent of nodes as advance nodes with energy factor 1 (i.e. equipped with 1 times more energy than that other normal nodes).
- $m = 0.3$ and $\alpha = 1$ i.e. 30 percent of nodes as advance nodes with energy factor 1.
- $m = 0.3$ and $\alpha = 3$ i.e. 30 percent of nodes as advance nodes with energy factor 3 (i.e. equipped with 3 times more energy than that other normal nodes).

In Fig.5, we show the results of network lifetime. Nodes are considered dead after consuming initial energy. LEACH-PR protocol obtains the longest network lifetime and unstable region among the other three. This is because, here the energy consumption is well distributed among nodes. Network is divided in LEACH-PR into two logical regions and it balances energy consumption among sensor nodes and some nodes are put to off mode in each round to save energy without losing data. When there are 10 percent of advance node with factor $\alpha = 1$, last node dies in EEM-LEACH after 1970 rounds, in I-LEACH after 3800 rounds, in EHE-LEACH after 4100 rounds and in our protocol (LEACH-PR) continues after 5000 rounds with minimal energy.

So LEACH-PR outperforms 2.08 times than EEM-LEACH, 1.08 times than I-LEACH and 1.12 times than EHE-LEACH. So, the network life for LEACH-PR is increased as compared to others.

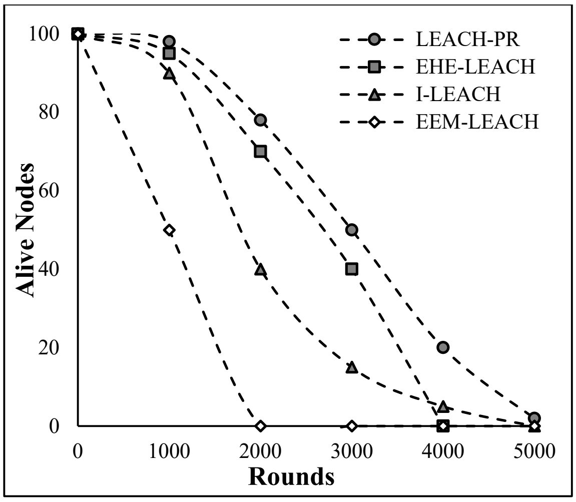

Fig.5. Comparison between I-LEACH, EHE-LEACH, EEM-LEACH, LEACH-PR presence of heterogeneity: Alive nodes vs. Rounds (m=0.1, α=1)

7.2.3 Radio Propagation Models in Urban Terrain:

Coverage prediction for technology like WiMAX [1] is done based on path loss and RSSI (Received Signal Strength Indication). Although there exists a numerous method to predict coverage, path loss and RSSI are used during the initial stages of deployment represents the reading for path loss at 3.5GHz.

From the Fig.6, it's clearly evident that MRRP-A performed better compared to the other radio propagation models at 3.5GHz in Urban environment. To be more precise, MRRP-A is more suitable for high path loss. Urban environments, due to obstacles have high path loss and as distance increases path loss also increases rapidly in urban environment. From the graph it is clearly that MRRP-A performed fairly good.

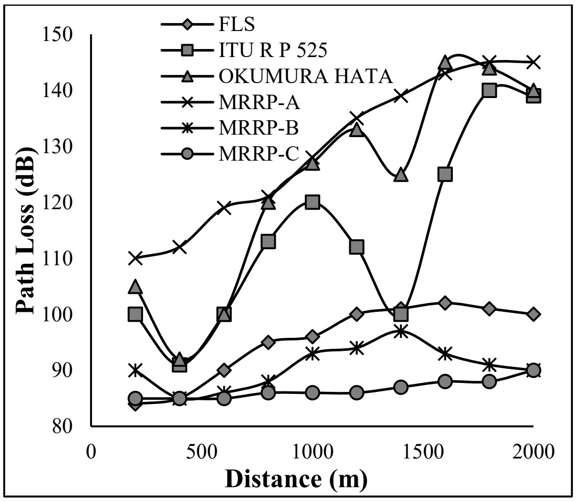

Fig.6. Path Loss predictions at 3.5GHz in Urban environment

7.2.4 Radio Propagation Models in Rural Terrain:

Best radio propagation model based on path loss in rural terrain with different frequency is showed in below Fig.6 that shows path loss results for three distinct frequencies in rural environment. MRRP–C proved to be the best model in the rural environment by predicting the lowest path loss. There exists a difference of 15dB between the higher operating frequencies (3.5GHz, 2.5GHz) and lower operating frequencies (450MHz). MRRP–C which is similar to MRRP-B for path loss predictions were done in rural environment in India. MRRP-B, flat region also termed as MRRP-C performed well compared to the other propagation models considered.

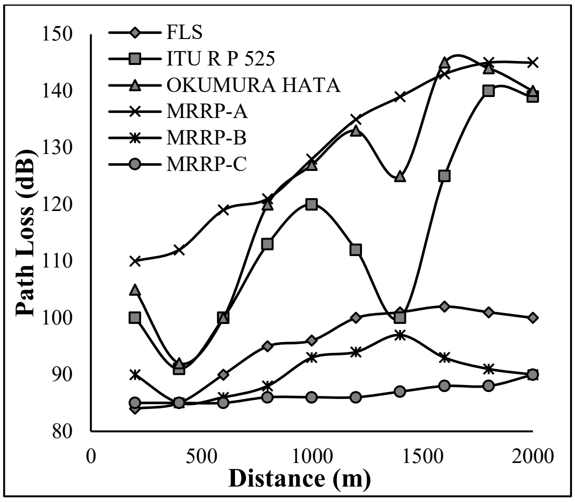

Fig.7. Path loss predictions at 3.5GHz in rural environment

The proposed LEACH-PR consists of clustering, routing and data transfer which is discussed in above two chapters. The proposed protocol used FEDC for efficient clustering, based on inter-cluster communication cost and RASSR for routing, based on efficient use of residual energy to prolong the network lifetime and data transfer for long distance with considerable free space path loss by MRRP model.

The proposed approach, FEDC mechanism is used to select the CHs to form the clusters and produces a uniform distribution of CH across the network, through localized communications with slight overhead. In LEACH-PR nodes switch between sleep and active modes in order to minimize energy consumption by implementing RASSR. The test has been conducted with three different parameter settings and each of m% advance nodes has factor of α times more energy, during most of the network lifetime, LEACH-PR runs with much more living nodes than other LEACH.

8. CONCLUSION

LEACH-PR includes advance propagation model (MRRP), which plays a very significant role in data transmission by finding the path loss at different operating frequencies. Coverage analysis is evaluated based on RSSI measurements by varying the modulation and coding scheme to understand performance in real time environment. For path loss evaluation, a total of 9 scenarios are evaluated to identify the best propagation model for long distance communication (WiMAX) in 3 different terrains at different operating frequencies.

Additional and advanced strategy to improve the performance of the WSN and make the network reliable and more efficient, has to be desired. Some idea would be like that we can add a mechanism where inter CH communication will increase the lifetime of those CHs which are far away from the BS. We can also employ an energy efficient security mechanism in heterogeneous sensor networks. This means, to achieve security in WSN, efficient key distribution and management mechanisms have to apply on lightweight sensors so that security is maintained.

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