Avoiding Energy Holes Problem using Load Balancing Approach in Wireless Sensor Network

Bhagyalakshmi Lakshminarayanan[1] and Murugan Krishanan[2]
[1,2] Ramanujan Computing Centre, Anna university,
Chennai – 600 025, India
[1][e-mail: eec.ecetimes @gmail.com], [2][e-mail: murugan@annauniv.edu]
Correspondence Author: Bhagyalakshmi Lakshminarayanan

Received October 20, 2013; revised March 31, 2014; accepted April 10, 2014; published May 29, 2014

Abstract

Clustering wireless sensor network is an efficient way to reduce the energy consumption of individual nodes in a cluster. In clustering, multihop routing techniques increase the load of the Cluster head near the sink. This unbalanced load on the Cluster head increases its energy consumption, thereby Cluster heads die faster and create an energy hole problem. In this paper, we propose an Energy Balancing Cluster Head (EBCH) in wireless sensor network. At First, we balance the intra cluster load among the cluster heads, which results in nonuniform distribution of nodes over an unequal cluster size. The load received by the Cluster head in the cluster distributes their traffic towards direct and multihop transmission based on the load distribution ratio. Also, we balance the energy consumption among the cluster heads to design an optimum load distribution ratio. Simulation result shows that this approach guarantees to increase the network lifetime, thereby balancing cluster head energy.

Keywords: Energy hole, EBCH, load distribution, mixed routing, network lifetime, Wireless Sensor Network.

A preliminary version of this paper appeared in ICoAC 2012, December 13-15, Anna University, India. This version includes a mathematical analysis of non uniform distribution of node deployment and comparison with the existing work in the same issue.

http://dx.doi.org/10.3837/tiis.2014.05.007

1. Introduction

Recent technological development of wireless sensor network is in the field of communication and computation. The wireless sensor network consists of battery operated device equipped with sensors which are used for sensing the environmental changes, data processing and communicating wirelessly either through the single or multi hop routing [1]. As the sensor nodes are battery operated they are limited with power, and when it runs out of energy, it is disconnected from the network. Hence, energy consumption is a critical factor in WSN which results in the design of protocol for efficient energy consumption which maximizes the lifetime of the network. If the entire sensor nodes transmit data directly to sink, data collision and network congestion occurs which in turn reduces the network lifetime and this issue can be handled by the clustering techniques in WSN.

In a Hierarchical clustering [2], the energy consumption can be reduced. The whole network is divided into clusters in which a node is selected as Cluster Head (CH) and remaining nodes are called member of the cluster. The nodes transmit their data to the respective CH which has inherent capabilities and perform data aggregations (intra-cluster communication) which in turn send the data directly to sink or through another CH to sink (inter-cluster communication) via a multi hop routing technique.

The data aggregation technique receives data from the sensor nodes aggregates into a single stream of data [3]. This technique is widely used in sensor nodes. Some aggregations Algorithm are centralized approach, like LEACH that prolong the network lifetime by dividing the network into clusters. The cluster head in the clusters is selected randomly and performs data aggregation. The sensor nodes have to send data periodically to Cluster head. The aggregated data from the cluster head will send directly to sink by selecting an efficient path.

Many protocols are proposed in various literatures to avoid the energy hole problem to extend the network lifetime, but a balancing of energy consumption among the cluster heads to avoid energy hole problem in WSN is not addressed much. In WSN with clustering technique, the energy consumption for inter-cluster traffic is compared more to that of intra-cluster traffic. In order to balance the inter-cluster energy consumption data propagation, algorithms are to be considered. EBDG protocol is designed efficiently for a corona based sensor network that provides balanced energy consumption among sensor nodes [4]. We provide an optimized load distribution ratio i.e. the probability of how much data propagates directly from the Cluster head to the sink.

In this paper, Energy balanced cluster head (EBCH) for corona based wireless sensor network is evaluated. In a WSN, for a multihop scenario where the sensor nodes near the sink receive the packets from distant nodes and relay the same to the sink. Thereby the nodes near the sink are overloaded that causes energy hole problem. This problem may be overcome by mixed routing approach. However in a clustering approach, mixed routing scheme depends on the load Distribution Ratio. If the load distribution ratio is the same for all the Cluster heads, then the CH near the sink will carry heavier load that leads to energy hole problem. In order to avoid this problem, two approaches are undertaken in EBCH. In the first approach, the intra cluster load of the cluster heads are balanced such that rises to a non uniform distribution of nodes in the cluster. In the second approach, energy of cluster heads are balanced, that gives the relationship of how much load is being transmitted directly to the sink, and between the Cluster heads, leads to a optimized load distribution ratio. Thus EBCH is the main motivation to avoid energy hole and prolong the network lifetime. The wireless sensor network is divided into concentric rings, called the corona, and further each ring is sectorized this results in the formation of unequal cluster. The CH in each cluster gathers the data from the general node and sends it to the sink through a mixed routing algorithm.

The main contributions of this paper are:

- A novel Energy balancing cluster head approach (EBCH) is proposed. In this approach, wireless sensor network is divided into coronas and then it is sectored to form unequal clusters. This scheme is adopted to maintain equilibrium in energy consumption among CHs.
- A Cluster head selection technique is applied to select CH. Each CH will do data compression over the received data and acts as a relay node to decide the next hop CH.
- To maintain minimum inter-cluster energy consumption of the network, the optimum load distribution model is designed such that load along the CHs are balanced, which in turn balance the energy consumption among CHs.
- Simulation experiments are conducted, from the results of the performances of EBCH approach to avoid energy hole problem and increase network lifetime.

The remaining part of the paper is organized as follows; the Introduction is given in section 1 then section 2 gives the overview idea of related work, while the system model and proposed work are explained in section 3. The estimation of energy consumption is done in section 4 followed by optimization analysis of Energy Balancing among Cluster Heads in section 5. The simulation setup and performance metrics along with simulation results and its analysis using various methods are provided in section 6. Finally, section 7 presents the conclusion of the paper with future work.

2. Related Work

Many approaches are made to avoid Energy hole problem on balancing the energy consumption using a suitable data gathering approach in WSN. The main aim of this approach is to extend the network lifetime and to avoid redundant data transmission to the sink. In this section, relevant papers are reviewed. Haibo Zhang and Hong Shen proposed EBDG protocol to avoid energy hole problem for uniformly deployed node in a corona based data gathering network on balancing energy consumption with the mixed routing condition along with data aggregation [4]. In EBDG protocol, data are distributed in the same ratio for all the nodes in the corona. The authors have applied a zone based routing scheme in which nodes in one zone, in the outer corona, have been mapped to the nodes of the zone in the inner corona. Obviously it is a tedious work in a large sensor network. A mathematical model to analyze the energy hole problem in WSN with uniform node distribution is developed in [5]. Authors of [5] have again validated several possible schemes from traffic point of view to avoid the energy hole problem in [6]. They have observed that hierarchical deployment of nodes and data aggregation technique had a positive approach. On the Hierarchical networks, the Low Energy Adaptive Clustering Hierarchy (LEACH) is an energy conserving cluster formation protocol [7]. The Cluster heads are primarily selected, based on the random threshold value given to the nodes in the cluster. The CHs are rotated in a random manner to set themselves to achieve energy consumption in a balanced form. The CH, after receiving, sends data directly to the sink with a single hop. The sink in larger scaled wireless sensor network is far off from the CHs formed at the periphery; hence it has limitation over large scaled wireless sensor network. LEACH is further extended by HEED which incorporates the CH selection based on the residual energy of the node and they are well distributed in the network [8]. The limitation of HEED is its inter-cluster communication, which is not addressed. Because of this limitation, the CH near the sink will be heavily loaded and thereby the energy consumption among the cluster heads are not balanced, thus gives rise to the energy hole problem and part of the network.

To solve the energy hole issue, a non uniform node distribution strategy is proposed in [9] and [10]. Authors have suggested three strategies. In the first strategy, the nodes are deployed in geometric node distributed to mitigate the energy hole problem and it had balanced the energy depletion in WSN. This strategy has its limitation since positioning the nodes in the network is a tedious work, as the sensor nodes are spread in a random manner. According to the second strategy, the nodes are placed based on the Energy proportion node distribution (EPND) in the uniform width corona model network. They had used a simple switch scheduling technique to decide whether the sensor should sense in that region or not. If sensor nodes are not sensing, either they should be idle or act as relay nodes. This strategy achieved by extending the network lifetime, but balancing energy consumption is not considered. The third strategy states that the corona type network is of non uniform width where the nodes in the outer region has large sensing and transmission range compared to the nodes in the inner most coronas. This strategy increases the network lifetime, but it has its own limitations over the number of nodes to be deployed.

Many multihop energy aware protocols are proposed for WSN. In Energy Efficient unequal clustering mechanism the cluster very close to the base station will have a smaller cluster size rather than the cluster far away from base station [11]. Simulation results show that the energy consumption is well balanced among the cluster nodes. The authors developed a clustering scheme EECS [12] which suits periodical data gathering. The Cluster Head will be selected based on the residual energy and hence CHs are well distributed. In a large scale network, to save energy consumption multihop communication is to be exhibited but EECS concentrated on single hop communication and hence energy efficient protocols are not discussed. Energy efficient geographic routing in wireless sensor networks (EEGR) [13] enables efficient energy consumption with localized information and routing decisions in uniformly distributed wireless sensor network. The Energy consumption is estimated approximately, hence providing energy efficient routing is a tedious job. The Protocol EECRP in [14] is a chain based Efficient Energy Consumption Protocol to increase the network lifetime. EECRP set horizontal chain to communicate among sensor nodes to transmit data to their cluster head, the vertical chain creates a connection between chain head to transmit data to the leader node which finally send to sink. Data transmission between the sensor nodes appears in horizontal direction and among the cluster heads in vertical direction. Another clustering scheme was proposed in [15] is based on the correlation of sensor data. In DCC, the Cluster heads transmit a simple TDMA schedule to intimate its member when their data to be sent. The Cluster head, gathers the data according to TDMA schedule. This clustering Algorithm significantly improves the suppression rate, but increases the correlation among the nodes within their cluster. This protocol reduces the traffic to the sink and enhances the network lifetime.

3. System Model and Problem Statement

3.1 Network model

The network model proposed in this paper is adapted from [16]. In this model the sensor nodes are distributed in a cone shaped sensing area A of radius$R$, having a central angle 2β. This area is the part of the large circular region or any other general shape. The nodes in the region are homogeneous in nature with the common initial energy and the transmission radius $r_{th}$where $r_{th} > R$. The energy consumption of the sensor nodes varies based on the transmission distance to reach the receiver. With reference to the previous work, the data gathering is done in rounds. In each round, the cluster nodes transmit data to the CH that performs data compression with factor m $(0 \leq m \leq 1)$ and then, transmits the data to the sink using the mixed routing technique. In this process, every node generates L bits of data in each round. Finally an ideal MAC is considered which implies that there is no collision and retransmission and each link has enough capacity to transfer data in a well connected network.

3.2 Energy and data compression model

The radio model proposed in [17] [18] [19] [20] is to measure the energy consumption in the wireless communication. In this model energy consumption spent by transmitting L bits of data over a distance x is defined as $E(x) = E_{elect}\, L + E_{fs}\, (x^k)L$ where E_{elect} is the energy spent by the transmitter, E_{fs} the energy spent by transmitting amplifier and k is the propagation constant, where $k = 2$ for free space. While receiving data, the energy spent for a single bit is given as $E(x) = E_{elect}$. Since all the nodes will generate uniform data and it is balanced among the nodes, hence, energy consumption for sensing the data is ignored. A Data Compression model proposed in [21] is applied here. The amount of data output of the cluster head is the function of input data u, denoted by $C(u)$such that $C(u) = mu + b$. There arises different scenarios depending on the different value of m and b. For $0 < m < 1$ and $b = 0$, the cluster head can compress the received data by the factor m in this proposed model.

3.3. Problem Statement

The monitoring area A is equally divided into n concentric rings (coronas) called homogenous clusters, designated as $C1$, $C2$, $C3$, etc. with their respected node densities $\rho1$, $\rho2$, $\rho3$, etc. as shown in **Fig. 1**. The sink is placed at the center of the network. The width of the cluster will remain same as w where $w = R/n$ and R is the radius of the network. It is known that in a corona type network the energy hole is an inherent issue when multi hop routing technique is used. To avoid energy hole problem, a control region in the centre as centroid and radius r is formed. The nodes residing in this region are termed as control region nodes. The nodes outside the control region are called as common nodes. The cluster head node is selected from the set of control region nodes, which does data compression over the received loads and transmits to the sink as well as, to the next hop CH in the inner cluster.

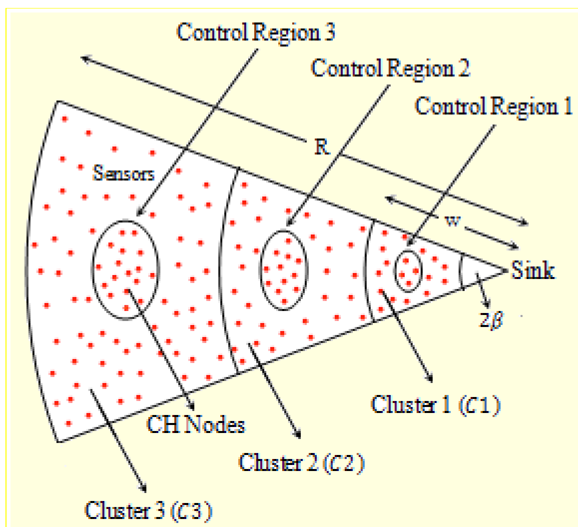

Fig.1. Unequal clustering in a corona based model.

The energy consumption is categorized in two ways, namely, intra-cluster energy consumption and inter-cluster energy consumption. The former, which is intra-cluster energy consumption corresponds to the sum of energy consumed by the common nodes while transmitting the data to the corresponding cluster head and the energy dissipated by the cluster head while receiving and then compressing the data. The latter comprises of the energy spent by the cluster head while transmitting the data to other next hop CH and the sink.

The inter-cluster energy consumption will be more for large scale WSN compared with intra-cluster energy. To balance the inter-cluster energy consumption among the CHs, the compressed load will be sliced by the CH towards direct and hop by hop transmission. The slicing of the load is done based on the load distribution ratio [22]. During hop by hop transmission, the CH in C_k Cluster forwards a part of data to the next CH in C_{k-1} cluster and remaining data directly to the sink.

We assume that all the CHs in their respective clusters will have the optimized load distribution ratio for direct and hop by hop transmission. We will focus on the measures taken to avoid energy hole problem:

(1) How to balance the energy consumption among the CHs (EBCH) in different clusters.

(2) How to compute the load distribution ratio (P) for the CH towards direct and hop by hop transmission.

4. Estimation of Energy Consumption

This section concentrates on how to estimate the intra-cluster and inter-cluster energy consumption by common nodes and cluster heads respectively.

4.1 Identification of Control Region

The nodes are distributed non uniformly in the network as shown in **Fig. 1.** All nodes sense the data and route their data packets to the cluster head present in the cluster. To extend the lifetime of the network, the cluster heads must be presented in the centroid position of the cluster. Initially the node which is very near to the centroid or on the centroid is selected as the cluster head. When the nodes are distributed, it is hard to find the node exactly at the centroid position, hence a circular region with the centroid as center and radius r called as centroid region or control region, is formed. The radius r of the control region is proportional to the transmit distance between centroid point in the cluster and sink. The radius r is very small since we are finding nodes, which are very near to the centroid point. Calculation of centroid points of the clusters are given in equation (1). The centroid point of the $1^{st}, 2^{nd}, \ldots\ldots k^{th}$ cluster is located using the Polar coordinates $(d_1, \beta), (d_2, \beta) \ldots (d_k, \beta)$. Distance from the center O to the centroid in cluster $1, 2, \ldots k$ is represented by d_1, $d_2, \ldots d_k$ respectively are obtained by the following expression.

$$d_1 = \frac{\int_0^w w^2 \, 2\sin\left(\frac{\theta}{2}\right) \, dw}{w^2 \left(\frac{\theta}{2}\right)} = \frac{2\, w \sin\left(\frac{\beta}{2}\right)}{3\left(\frac{\beta}{2}\right)} \tag{1}$$

Distance from the center 'o' to the centroid in cluster 2

$$d_2 = \frac{2}{3} * \frac{(2w)^3 - (w^3)}{(2w)^2 - (w^2)} * \frac{\sin\left(\frac{\beta}{2}\right)}{\left(\frac{\beta}{2}\right)} \tag{2}$$

In general, Distance from the center 'o' to the centroid in cluster K

$$d_k = \frac{2}{3} * \frac{(kw)^3 - \left((k-1)w\right)^3}{(kw)^2 - \left((k-1)w\right)^2} * \frac{sin(\beta)}{(\beta)} \tag{3}$$

4.2. Cluster Head Selection and Data Propagation

The nodes are location aware since all sensor nodes are assumed to be equipped with GPS antenna. Thereafter the distance of each node from the centroid of the cluster will be estimated. If the estimated distance is less than the radius of the centroid region r then these nodes will be identified as control region nodes for which IDs are created. Initially during the first round of data gathering, the CH will be selected from the set of control region nodes based on the nearest distance to the centroid since all other control region nodes will have the same residual energy. The selected CH will broadcast its ID message to all nodes in the cluster. The non CH nodes will send $a\ L\ bit$ of data along with residual energy.

After the first round of data gathering, the CH will send an acknowledgement message (ACK) along with an ID message of new CH to all nodes. The new CH node from the control region nodes is selected which has minimum distance from the centroid and maximum residual energy. At a time only one node will be selected as CH and all other nodes, either inside or outside the control region, will transmit the data to the CH. The CH will, now, compress the gathered data, from its members, by factor m. The CH will send part of the data to the CH in the inner cluster and remaining data directly to the sink.

In this phase, the intra-cluster data, sensed by common nodes, are sent to respective cluster head. The energy dissipated by nodes in their cluster while transmitting the data to the respective cluster head is estimated, with reference to **Fig. 2 (a),** as followed.

Let x be the radial distance from the sink to a common node present in the k^{th}cluster (CH_k). The distance between cluster head CH_k and the sink is denoted by d_k. Let θ is the angle deviated from the cluster head to the common node. The deviation from central angle and the deviation of radial distance in the cluster are represented by $d\theta$ and dx respectively as illustrated in **Fig. 2 (b).**

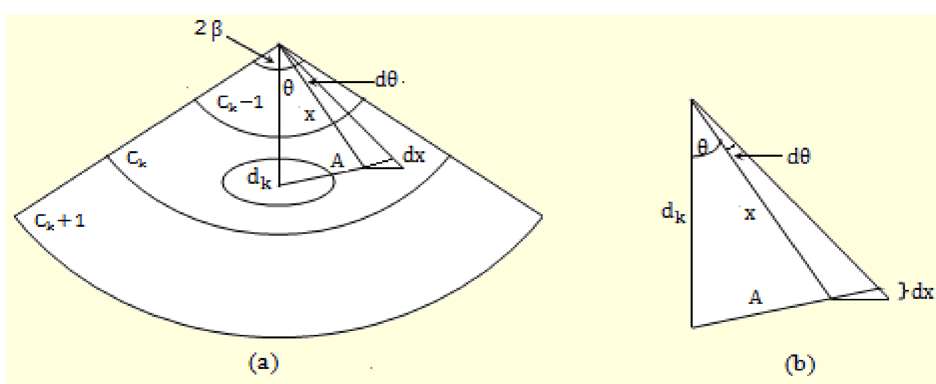

Fig. 2. a) Calculation for energy dissipation of common nodes in cluster 2, **b)** Enlarge view of calculating area.

The distance between the cluster head and common node is taken as A. According to the cosine formula A can be defined as

$$A^2 = d_k^2 + x^2 - 2d_k x cos\theta \tag{4}$$

According to the energy model, the total energy consumed by the general nodes in cluster C_k while transmitting L bit of data to the cluster head is given as

$$E_{trans} = 2\rho_k E_{elect} L \int_{((k-1)w)}^{(kw)} \int_0^{\beta} x dx\, d\theta + 2\rho_k E_{fs} L \int_{((k-1)w)}^{(kw)} \int_0^{\beta} (A^2) x dx d\theta$$

substitute (4) in the above equation, we get

$$E_{trans} = 2\rho_k E_{elect} L \int_{((k-1)w)}^{(kw)} \int_0^{\beta} x dx\, d\theta + 2\rho_k E_{fs} L \int_{((k-1)w)}^{(kw)} \int_0^{\beta} \left({d_k}^2 + x^2 - 2d_k x \cos\theta \right) x dx d\theta$$

On simplification, the total energy will be,

$$E_{trans} = (2k-1)\beta w^2 \rho_k E_{elect} L + (2k-1)\rho_k E_{fs} d_k^2 \beta w^2 L - \frac{4}{3} \rho_k E_{fs}\ d_k\ \sin\beta w^3 [k^3 - (k-1)^3] L + \frac{\rho_k}{2} E_{fs} \beta w^4 [k^4 - (k-1)^4]\, L \tag{5}$$

All nodes in the network maintain its local information in its clusters. Further the centroid distance d_k is estimated with respect to node density ρ_k of the cluster k. In a WSN, average energy consumed can be estimated as E_{trans}/N_k and $N_k = A_K\, \rho_k$ where N_k is the number of nodes and A_K is the area of cluster$k$.

4.3. Computation of Energy consumed by Cluster Heads

The energy consumed by CH is estimated during receiving data (E_{CHR}) and data compression technique (E_{CHcomp}). The area of the cluster k is given by$(2k-1)\beta w^2$. The number of sensor nodes other than CH in the cluster k is, then, given by the expression $((2k-1)\beta w^2\, \rho_K - 1)$. Since each node generates L bits of data per round, the total amount of data received by cluster head is, thus, calculated as

$((2k-1)\beta w^2\, \rho_k - 1)L$ therefore,

$$E_{CHR} = ((2k-1)\beta w^2\, \rho_k - 1) L E_{elect}\ ; \qquad for\ k = n \text{ (outer most cluster)}$$

$$E_{CHR} = ((2k-1)\beta w^2 \rho_k - 1)\, L E_{elect} + Y_{(K+1)} E_{elect}\ ; \qquad for\ k = 1,2,3, \dots . n-1 \tag{6}$$

Where $Y_{(K+1)}$ is the amount of data transmitted from the outer most cluster head to the inner cluster head. Similarly, energy consumed by CH while data compression, is estimated at

$$E_{CHcomp} = \left((2k-1)w^2\beta\rho_k L\right)E_{df}\,; \qquad for \quad k = 1,2\ldots n \tag{7}$$

Where E_{df} is the energy consumed during data compression by the Cluster head.

4.4. Inter Cluster Energy consumed by Cluster Head

The energy consumed by CH in the cluster k while transmitting Y_k data, in one hop, to the CH of cluster $k-1$ and remaining $X_k$data directly to the sink is estimated in this section. The tradeoff between traffic through hop by hop and direct to sink is defined by the load distribution factor P. Hence the energy consumed by the cluster head, while transmitting, is given by

$$E_{CH_{k(trans)}} = X_k\left(E_{elect} + E_{fs}{d_k}^2\right) + Y_k\left(E_{elect} + E_{fs}w^2\right);$$
$$for\ k = n, n-1, \ldots \ldots .2,1 \tag{8}$$

5. Energy Balancing among Cluster Heads

The sensors in the homogenous cluster forward their data packets to the respective CH. The CH in the inner most cluster will transmit the data directly to the sink. The cluster head in cluster k will receive Y_{k+1} load from the CH present in cluster$(k+1)$. The total load of CH in cluster k follows the load distribution ratio to forward X_k data directly to the sink and Y_k data to the cluster head present in the cluster$(k-1)$. To balance the energy dissipated by the cluster head, the load distribution ratio is defined in terms of probability of load distribution P where $0 \leq P \leq 1$. The Probability of load distribution of CH for the Cluster k while sending data directly to the sink is given by,

$$P(CH_k) = \frac{X_k}{Total\ traffic\ at\ CH} = \frac{X_k}{X_k + Y_k} \tag{9}$$

Hence the probability of sending the data through hop by hop is given by $1 - P(CH_k)$. The traffic received from the cluster heads CH_1, CH_2, CH_3, and CH_4 of the different clusters 1, 2, 3 and 4 is mapped in a chain model as shown in **Fig. 3.**

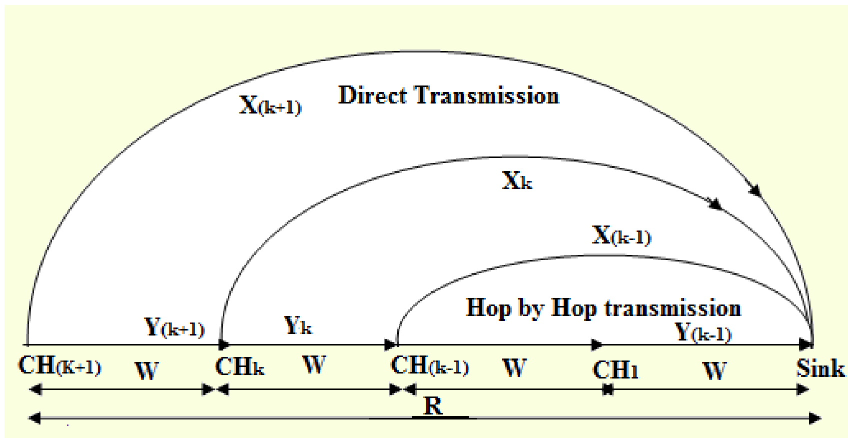

Fig. 3. load distribution at the cluster head.

In the load Balancing approach goal is not only to balance the load generated among cluster heads but also to balance the transmission energy of cluster heads for transmitting the data directly to the sink. In this approach the inner most cluster and the outer most clusters are not considered. The analysis of load at cluster heads CH_k and at CH_{k-1} is given as Intra cluster load (data transmitted by common nodes to the CH in respective cluster) generated to $CH_k = (2k-1)w^2\rho_k Lm\beta$. Intra cluster load generated to $CH_{k-1} = (2k-3)w^2\rho_{k-1}Lm\beta$.

By equating the above equations,

$$(2k-1)\rho_k = (2k-3)\rho_{k-1} \;\; then \;\; \frac{\rho_k}{\rho_{k-1}} = \frac{(2k-3)}{(2k-1)}$$

Hence we can extend it as follows

$$\frac{\rho_{k+1}}{\rho_k} = \frac{(2k-1)}{(2k+1)}$$

and implies that

$$\rho_{k+1} < \rho_k < \rho_{k-1} \quad (10)$$

It is concluded that the node density of the outer cluster is less than the node density of the inner cluster.

5.1. Balancing the Direct Transmission energy Consumption

The energy consumed by the Cluster head will be more when it sends the data directly to the sink comparatively with one hop distance to next CH. If this direct transmission energy consumption of CHs of two different clusters gets balanced, then the lifetime of the network may be extended. The energy consumption during transmission among the cluster heads in two different clusters are estimated. At the equilibrium condition,

$E_{CH_{k(direct)}} = E_{CH_{k-1(direct)}}$ then, $X_k \left(E_{elect} + E_{fs}\, {d_k}^2\right) = X_{k-1}\left(E_{elect} + E_{fs}\, {d_{k-1}}^2\right)$

Rearranging the terms, $X_k\, {d_k}^2 = X_{k-1}\, {d_{k-1}}^2$. It can be concluded that,

$$X_{k+1} < X_k < X_{k-1} \qquad since\ \ d_{k+1} > d_k > d_{k-1}\ ; \qquad for\ 2 < k < n \qquad (11)$$

further $X_{k+1} < Y_{k+1}$ (outer most) $X_k \leq Y_k$; and $X_{k-1} \leq Y_{k-1}$

$Hence,$ $P(CH_{K+1}) < 0.5$ (outer most cluster)

$P(CH_K) \leq 0.5$;

$P(CH_K) \leq P(CH_{K-1}) \leq 0.5$

It is concluded that the CH from the outer cluster will transmit less data to sink compared to the inner CH in the network. Also it is declared that the data directly to transmitted to sink is less than that of the data transmitted to the next hop CH. The algorithm for balancing the direct transmission energy among the cluster heads is presented in **Fig. 4.**

1. Cluster Configuration
   - i. (if $(k-2)w \leq x \leq (k-1)w$)& $(0 \leq \theta \leq 2\beta)$)
     Area = $(k-1)th$ cluster
   - ii (if $(k-1)w \leq x \leq kw)$ & $(0 \leq \theta \leq 2\beta)$)
     Area = kth cluster
   - iii. (if $(kw \leq x \leq (k+1)w)$&$(0 \leq \theta \leq 2\beta)$)
     Area = $(k+1)th$ cluster
2. Find the centroid of each cluster formed by polar coordinates
3. Form control region in cluster with radius r and center as centroid
4. Identify the cluster head by their IDs.
5. Select the cluster head
6. Data collection by cluster head (CH)
   - a. Balancing Intra-cluster data to CH as per equation (10)
   - b. Data length generated by CH
   - c. Data compression by CH
   - d. Inter cluster data collection by CH
     - i. $Design\ P(CH_{k+1})$ < 0.5
       if (Node = cluster head of cluster K+1) outer most cluster
       $Transmit\ Y_{K+1}\ data\ to\ (CH_k) = (1 - P(CH_{k+1}))\ (c(u))$
       if (Next node = Sink)
       $Transmit\ X_{K+1}\ data\ to\ sink = P((CH_{k+1}))\ (c(u))$
     - ii. $Design\ P(CH_{k+1}) \leq P(CH_k) \leq$ 0.5
       if (Node = cluster head of cluster K)
       $Transmit\ Y_K\ data\ to\ (CH_{k-1}) = (1 - P(CH_k))\ (c(u) + Y_{K+1})$
       if (Next node = Sink)
       $Transmit\ X_K\ data\ to\ sink = P((CH_k))\ (c(u) + Y_{K+1})$

7. Renewal Phase
   a. Cluster head enquires the energy level of the node inside the centroid region
   b. Select next CH node from the control region with highest residual energy
   c. Broadcast the new selection of cluster head in the cluster

Fig. 4. Algorithm for *EBCH*

6. Simulation Results and Analysis

In this section, the performance of load balancing approach among the CHs by balancing the average energy consumed by CHs is evaluated through simulations. The efficiency of EBCH is evaluated in terms of enhancing the network lifetime and balancing the energy consumption among the cluster heads, and also compared with EBCAG [23] and HEED. Finally EBCH is compared with LEACH and EBCAG based on the energy consumption by partitioning the entire network into 50 index regions. To verify the performance of EBCH the simulation parameters are summarized in **Table 1**.

Table 1. Simulation parameters

Simulation parameter	Value
Simulation area	$A = \pi r^2 * \frac{2\beta}{2\pi}$; where $R = 240\ mts$
Sensor nodes	600 nodes
No of sink	1 node
Packet size	2000 bits
Initial energy	4 Joules
E_{elect}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{df}	5 nJ/bit/signal
m (Compression factor)	0 to 1
k (Propagation constant)	2
P (Distribution ratio)	0 to 1

The average energy consumed by the CHs for data gathering rounds in the coronas 1, 2 and 3 are given as 1.35 mJ, 1.36 mJ and 1.4 mJ respectively as shown in **Fig. 5.** This result gives us the energy consumed by the CHs in each ring is balanced.

Fig. 6. gives us the amount of variance of energy consumed by the cluster heads with respect to number of rounds. As is seen in figure, The EBCH balances the energy consumption among CHs and it outperforms the HEED. In HEED the energy consumption among the CHs are not balanced. It is testified that the energy consumed by CHs in EBCAG and EBCH is balanced, but the variance of energy in EBCH is less than that of the

EBCAG. In EBCH, the load among the CHs is distributed based on the load distribution factor *P* towards the sink and next hop CH which brought variance of energy consumption of CHs well below than the variance of EBCAG.

The Efficient Energy consumption is estimated based on the number of alive sensor nodes as time elapsed which determines the network lifetime. The network lifetime is defined as the number of rounds at which the 5% of the sensor nodes run without energy. In the **Fig. 7.** it is shown that the all 600 nodes are maintained to survive till 103 iterations.

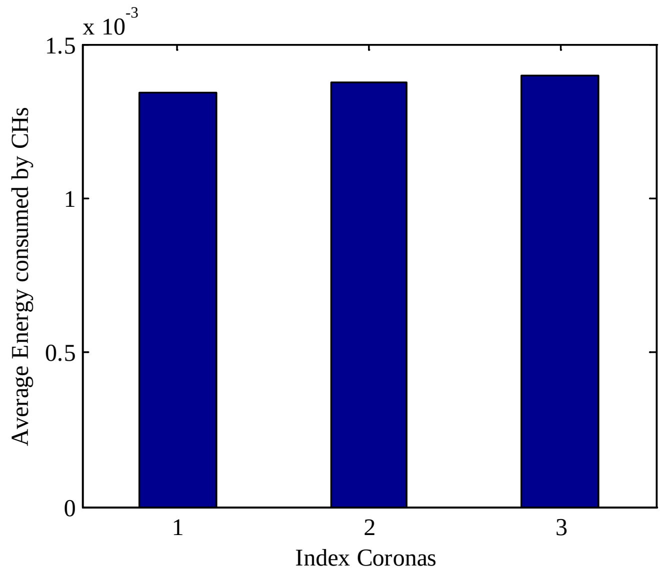

Fig. 5. Average energy (in joules) consumed by CHs.

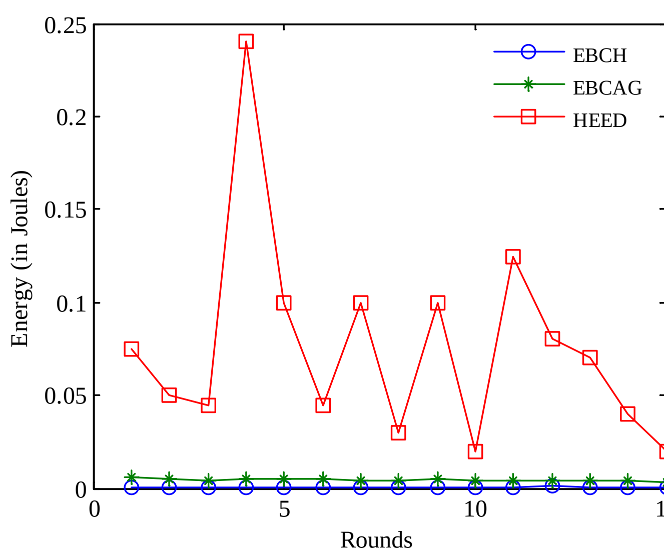

Fig. 6. Variance of energy consumed by cluster heads.

The important feature of this approach is to show that the number of alive nodes decreases almost linearly that indicates the EBCH prolongs the network lifetime. When compared to the EBCAG and HEED, the number of alive nodes over the simulation period is more in EBCH. Further, it implies that energy consumed by all nodes in the network is less than that of HEED and EBCAG.

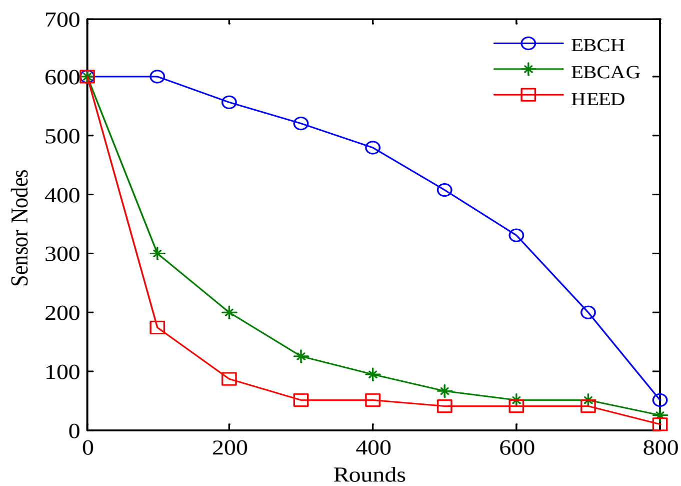

Fig. 7. Number of alive sensor nodes.

The comparison of initial energy to Network lifetime in terms of rounds (5% node dies) is illustrated in **Fig. 8.** It is evident from the figure7 the nodes contains an increasing trend of initial energy as number of rounds goes up to 170, whereas in other two schemes, the nodes can sustain the initial energy below 50 rounds.

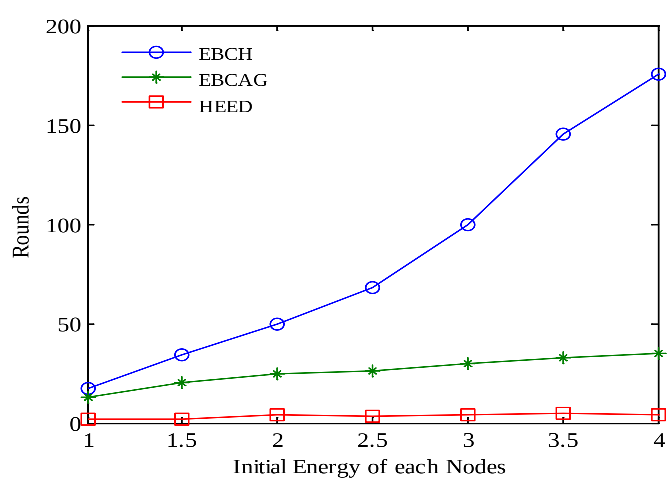

Fig. 8. Number rounds until 5% of nodes die with respect to initial energy (in joules) of each node.

The **Fig. 9** depicts the number of rounds until 5 % of nodes run out without energy. It is clearly shown that the EBCH increases the network lifetime when compared with two methods EBCAG and HEED. This is because of balancing the load along the CHs which, in turn, balances the energy consumption among the cluster heads.

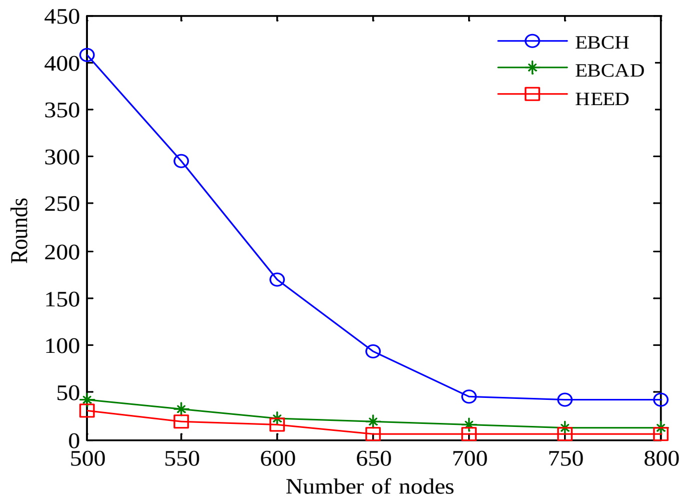

Fig. 9. Number rounds until 5% of nodes die with respect to the number of nodes.

In order to validate whether or not the energy consumption is balanced in the network, the entire network area (240 x 240 meters) is divided into 50 sub regions as shown in **Fig.10.** The average energy consumed by their nodes in the sub regions is further demonstrated and compared with LEACH and EBCAG for 50 rounds in **Fig. 11**. It clearly depicts that the average energy consumed in sub regions using EBCH approach is balanced and exceeds LEACH and EBCAG approach .The Energy efficiency of EBCH is more than that of LEACH. The average consumption of energy varies between 0.14 *J* to 0.34 *J* in LEACH whereas,in EBCAG it varies between 0.03J and 0.14J and in EBCH, it varies between 0.018 *J* and 0.02 *J* which is very less compared to LEACHand EBCAG.

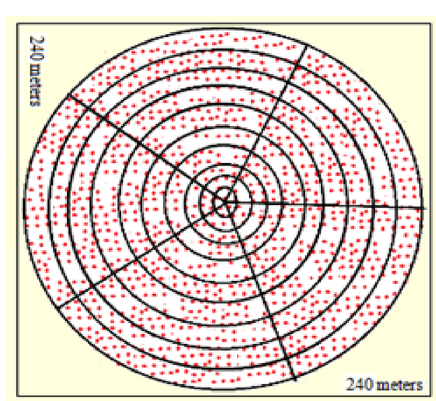

Fig. 10. Network Model

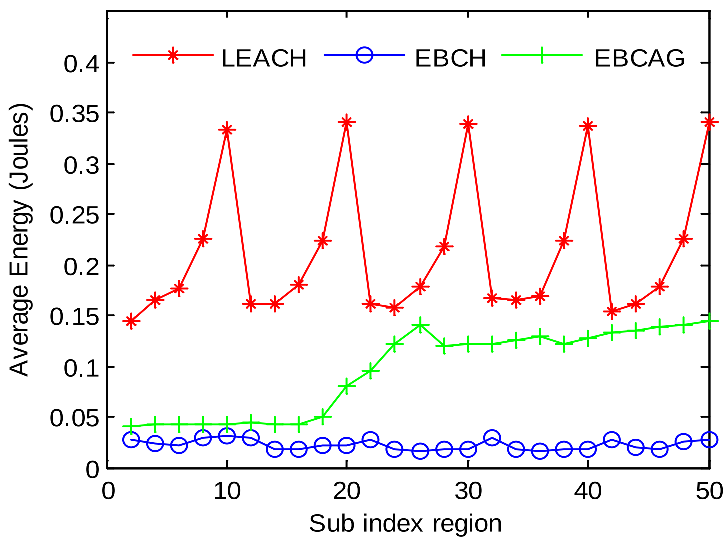

Fig. 11. Energy consumption (Joules) in the sub index region.

From the **Fig. 12,** it clearly states that the effect of the compression factor m over the received data from cluster head. The number of rounds increases to 450 at $m = 0.1$ and further the number of rounds decrease as m varies between 0.2 to 1. When $m = 1$ there is no compression over the received data. The proposed work EBCH is compared with EBCAG and it is concluded that the network lifetime in terms of rounds increases with respect to the compression factor m.

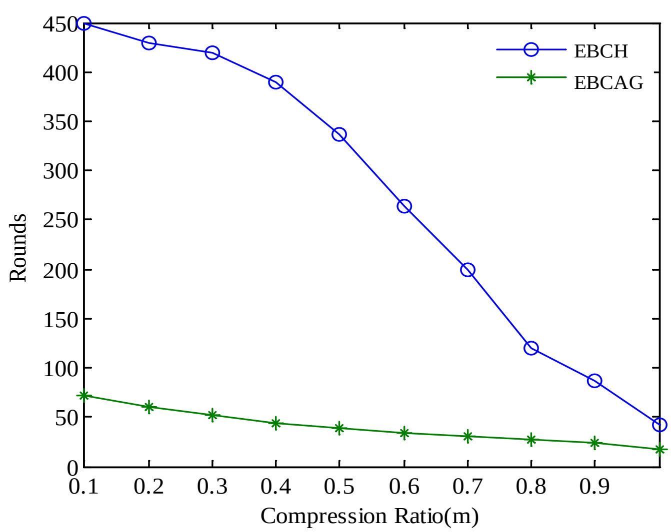

Fig. 12. Number of rounds until 5% of nodes dies with respect to the compression ratio.

7. Conclusion and Future Work

A novel method called Energy Balance Cluster Head (EBCH) is presented in this work to enhance the network lifetime by balancing the load among the Cluster heads. The formation of control region for selecting the Cluster heads at the beginning of operation is taken as a prime factor to have a better energy balance in the network. By analyzing the simulation results it is shown that proposed EBCH algorithm surpassed LEACH, HEED and EBCAG in terms of network lifetime and energy consumption. There are limitations too, during simulation; it is observed that common nodes in the outer most clusters die out first than the Cluster head nodes. The next limitation is the network size, since all the Cluster heads must be at the reachable distance of the sink. To avoid this limitation it is planned as a future direction of work to divide a big network into small clusters, as proposed in this work and the sink in the proposed work could be a cluster head with enormous energy E that would transmit the data to sink, kept at remote place.

References

[1] Ian F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "A survey on sensor networks," *IEEE Communications Magazine*, vol. 40, Issue 8, pp. 102–114, 2002. Article (CrossRef Link)

[2] Ameer Ahmed, Abasi and Mohamed Younis, "A survey on clustering algorithms for Wireless sensor networks," *Computer Communications*, vol. 30, Issue 14-15, pp. 2826–2841, 2011. Article (CrossRef Link)

[3] B. Krishnamachari, D. Estrin and S. Wicker, "The impact of data aggregation in wireless sensor networks," in *Proc. of 22nd International Conference on Distributed Computing Systems Workshops*, pp. 575–578, 2002. Article (CrossRef Link)

[4] Haibo Zhang and Hong Shen, "Balancing energy consumption to maximize network lifetime in data-gathering sensor networks," IEEE *Transactions on Parallel and Distributed Systems*, vol. 20, no. 10, pp. 1526–1539, 2009. Article (CrossRef Link)

[5] Jian Li and P. Mohapatra, "An analytical model for the energy hole problem in many-to-one sensor networks," in *Proc. of 62nd IEEE Vehicular Technology Conference (VTC-Fall 2005)*, pp.2721–2725, 2005. Article (CrossRef Link)

[6] Jian Li and P. Mohapatra, "Analytical modeling and mitigation techniques for the energy hole problems in sensor networks," *Pervasive and Mobile Computing*, vol. 3, no. 8, pp. 233–254, 2007. Article (CrossRef Link)

[7] W.R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proc. of 33rd Hawaii International Conference on System Sciences (HICSS 2000)*, pp. 4–7, 2000. Article (CrossRef Link)

[8] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient distributed clustering approach for ad hoc sensor networks," *IEEE Transaction Mobile Computing*, vol. 3, Issue 4, pp. 366–379, 2004. Article (CrossRef Link)

[9] Xiaobing Wu, Guihai Chen and Sajal.K. Das, "Avoiding energy holes in wireless sensor networks with non uniform node distribution," *IEEE Transactions on Parallel and Distributed System*, vol. 19, no. 5, pp. 710–720, 2008. Article (CrossRef Link)

[10] Huei–wen Ferng, Mardianto Soebagio and Arief Kurniawan,"Design of novel node distribution strategies in corona based wireless sensor networks," *IEEE Transactions on Mobile Computing*, vol. 10, no. 9, pp. 1297–1311, 2011. Article (CrossRef Link)
[11] Chengfa Li, Mao Ye, Guihai Chen and Jie Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks", *IEEE International Mobile Ad hoc and Sensor Systems Conference*, 2005. Article (CrossRef Link)
[12] Mao Ye, Chengfa Li, Guihai Chen and Jie Wu, "EECS: An energy efficient clustering scheme in wireless sensor networks," in *Proc. of 24th IEEE International Conference on Performance, Computing, and Communications (IPCCC 2005)*, pp. 535–540, 2005. Article (CrossRef Link)
[13] H. Zhang and H. Shen, "EEGR: Energy-efficient geographic routing in wireless sensor networks," in *Proc. of IEEE International Conference on Parallel Processing (ICPP)*, 2007. Article (CrossRef Link)
[14] Razieh Sheikhpour and SamJabbehdari, "An Energy Efficient Chain-based Routing Protocol for Wireless Sensor Networks," *KSII Transactions on Internet and Information Systems*, vol No 7, no.6, pp. 1357-1378,June 2013. Article (CrossRef Link)
[15] Myungho Yeo, Dongmin Seo and Jaesoo Yoo, "Data Correlation-Based Clustering Algorithms in Wireless Sensor Networks," *KSII Transactions on Internet and Information Systems*, vol No. 3, no. 3, pp. 331-343, June 2009. Article (CrossRef Link)
[16] L. Bhagyalakshmi, Sanjay Kumar Suman and K. Murugan, "Corona based clustering with mixed routing and data aggregation to avoid energy hole problem in wireless sensor network," in *Proc. of Fourth International Conference on Advanced Computing (ICoAC 2012)*, 2012. Article (CrossRef Link)
[17] M. Bhardwaj, T. Garnett and A.P. Chandrakasan, "Upper bounds on the lifetime of sensor networks," *IEEE International Conference on Communication (ICC 2001)*, pp. 785–790, 2001. Article (CrossRef Link)
[18] Qun Li, J. Aslam and D. Rus, "Distributed energy-conserving routing protocols for sensor network," in *Proc. of 36th Hawaii International Conference on System Science (HICSS 2003)*, 2003. Article (CrossRef Link)
[19] T. Melodia, D. Pompili and I.F. Akyildiz, "Optimal local topology knowledge for energy efficient geographical routing in sensor networks," in *Proc. of 23rd Annual Joint Conference of IEEE Computer and Communications Societies (INFOCOM 2004)*, pp. 1705–1716, 2004. Article (CrossRef Link)
[20] I. Stojmenovic and X. Lin, "Power-aware localized routing in wireless networks," *IEEE Transaction on Parallel and Distributed Systems*,vol. 12, Issue 11, pp. 1122–1133, 2001. Article (CrossRef Link)
[21] V. Mhatre and C. Rosenberg, "Design guidelines for wireless sensor networks: communication, clustering and aggregation," *Ad Hoc Networks*, vol. 2, pp. 45–63, 2004. Article (CrossRef Link)
[22] A. Jarry, P. Leone, O. Powell and J. Rolim, "An optimal data propagation algorithm for maximizing the lifespan of sensor networks," in *Proc. of 2nd International Conference on Distributed Computing in Sensor Systems (DCOSS 2006)*, pp. 405–421, 2006. Article (CrossRef Link)
[23] Tao Liu, Qingrui Li and Ping Liang, "An energy-balancing clustering approach for gradient-based routing in wireless sensor networks," *Computer Communications*, vol. 35, pp. 2150–216, 2012. Article (CrossRef Link)

L. Bhagyalakshmi had done his M.E in Electronics from Anna University, MIT campus, Chennai. She is currently pursuing research in the area of wireless sensor network in the Dept. of RCC, Anna University, Chennai, India. Her area of interest includes Wireless Ad hoc and Sensor Networks, Signal processing and Communication engineering.

Krishnan Murugan received his PhD degree under the Faculty of Information and Communication Engineering at Anna University, Chennai. He did his Master degree in Computer Science and Engineering, at National Institute of Technology (Formerly REC), Tiruchirapalli. He is currently working as Associate professor in Ramanujan Computing Centre, Anna University, Chennai, India . He is a life member of ISTE, IETE and CSI. His area of interest includes Mobile computing, MANETs and Wireless Sensor Networks.