



Energy Efficient Clustering and Random data Aggregation in Wireless Sensor Networks

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Abstract: *Wireless Sensor Network is a large group of dedicated equipments with a communication infrastructure intended to supervise and document conditions at diverse locations. Sensor nodes are limited in power. It is difficult to recharge the battery of sensor. Energy preservation is the main issue of WSN. Clustering and Aggregation are the energy efficient methods. To deal this issue, EECRA (Energy Efficient Clustering and Random data Aggregation in Wireless Sensor Networks) is proposed. In the proposed algorithm the network is divided into subnets called as clusters and head for the cluster is selected based on the number of neighbors, residual energy and distance of a node from the centre of the cluster. And also data are collected only from a subset of nodes. Simulation results show that the proposed algorithm achieves higher energy efficiency and increases network lifetime.*

Keywords: *Aggregation, Clustering, Energy efficiency, Wireless Sensor Network.*

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are the networks of light weight sensors mainly used for monitoring purposes. They monitor the physical parameters such as temperature humidity and etc. They need to send the sensed data to the Base Station continuously. Due to limited and non rechargeable energy provision of sensors, improving energy efficiency, maximizing the network lifetime and balancing the energy consumption of all nodes are the major challenges in the research of WSNs.[1],[2]. The energy of sensor node is mainly consumed by the communication unit, computing unit and sensing unit out of which the wireless transceiver uses a large portion of energy. The traffic follows a multi hop pattern where intermediate nodes deplete their energy faster. Therefore the unbalanced energy consumption is the main problem which needs to be solved to prolong the network lifetime.[4],[5].

Clustering method for data aggregation [7] in wireless sensor network has great attention for its high energy efficiency. The data traffic can be reduced by applying data aggregation at cluster heads [8]. It significantly reduces battery drainage of individual sensor nodes and also simplifies the network management. The topology structure for data aggregation may be classified into flat structure and hierarchical structure. The hierarchical structure has many advantages such as scalability, load balancing and high efficiency of data aggregation etc [8][10][11].

Motivated by the advantages of hierarchical topology structure, this paper proposed an Energy Efficient Clustering and Random data Aggregation in Wireless Sensor Networks (EECRA) algorithm for WSNs. In the clustering phase, nodes are grouped into clusters. In the cluster head (CH) selection phase, nodes near to the centre of the cluster are taken as candidate CHs. In addition a node that has maximum residual energy and better connectivity among neighbors is taken as cluster head (CH). Further in order to reduce energy consumption during aggregation, Cluster head selects subset of nodes and gathers data from them. This greatly saves energy and increases lifetime of the network.

In the rest of the paper, we review the related works in section II and the proposed algorithm in section III followed by performance analysis in section IV and conclusion in section V.

II. RELATED WORKS

LEACH [1] is a cluster based protocol. It is one of the first hierarchical routing approaches for sensor networks. LEACH randomly selects nodes as cluster heads and rotates this role among all sensor nodes to balance the load in the network. Each cluster head receives data according to a TDMA slot and compress the data before delivering it to the base station.

LEACH allows building single hop cluster and thus leads to large number of clusters causing great energy consumption of communications. It gives equal probability for nodes to become cluster heads but it does not consider the residual energy and location of the nodes.

V-LEACH [2] - it is a new version of LEACH protocol. Each cluster has two cluster heads (CH). Main CH is responsible for sending aggregated data to the BS and the Vice CH is responsible for gathering data from cluster members. If the main CH dies the Vice-CH will become cluster head. But it is unnecessary to elect a substitute cluster head.

A novel clustering based on K-means [3] algorithm is used to form the clusters based on Euclidean distances between nodes. It selects k- nodes randomly as cluster heads. Nodes decide its CH near to it according to the Euclidean distance. Now the centroid of the cluster is calculated. A node which is near to the centroid will be taken as new cluster head and then it does re clustering based on the new cluster head. This approach minimizes the energy consumed for the

sensor nodes to send data to the CH. And also the power consumption of CH is also less. But this K-means approach spends most of the time in clustering and re clustering and thus leads to greater energy consumption. And also it forms the clusters based on position of the nodes and thus leads to many clusters.

DSBCA [4] - A load balanced clustering algorithm deals the stochastic distribution of sensor nodes. It generates balanced clusters. The cluster radius can be determined by density and the distance from the base station. With farther distance from the base station and lower connectivity density the cluster radius is larger. Each member in the cluster calculates its weight and a node with higher weight is taken as CH. Weight is a measure of residual energy, number of neighbors and the number of times the node was elected as CH. It creates unequal clusters. DSBCA also limits the number of nodes in a cluster. The drawback of this algorithm is that it consumes more energy for communication and also it takes more time for calculating weight during cluster head selection.

EET[6] – Event driven clustering technique that reports data only when an event occurs. In this technique a threshold is set, and the sensors data with significant change more than the threshold are transmitted to the base station. Upon the detection of an event the sensors are grouped into clusters and one sensor was selected as cluster head and that will send data to base station. Clusters are reset when the situation becomes stable. The drawback in this is it is not suitable for applications which require continuous monitoring.

Cluster based approximate data collection [9] –proposes a doorway algorithm for approximate data collection. It sets two thresholds such as maximum bound value and minimum bound value. Whenever a packet arrives it checks the average queue size with the two thresholds. If it exceeds then it will drop the packets. It tries to reduce the congestion but it does not consider the significance of the data.

In our proposed scheme we generate balanced clusters by gradually increasing the radius of the clusters. And the cluster head selection process is limited only to the nodes near to the centre of the cluster having maximal residual energy and maximum number of neighbors .In order to reduce the number of transmissions and to save energy of sensors each Cluster head selects subset of nodes and gathers data from them.

III. PROPOSED SCHEME

Sensor network is represented as a graph $G<V, E>$ in our proposed work. Where $V= \{v1, v2, \dots, vn\}$ is the set of sensors and E is the set of edges. The following assumptions are made in our proposed system. They are

- The position of Base Station (BS) and sensor nodes are fixed.
- Nodes are randomly distributed.
- Each node has a unique identifier.
- All sensors are initialized with same energy
- Links are symmetric
- A node can compute distance to another node based on RSSI(Received Signal Strength Indicator)
- All sensors sense the environment and they will always have data to send to the BS.
- The size of each packet is same.

We use the same radio model as stated in [1]. To transmit an l -bit message from source to destination, the power consumption is defined by eqn. (1) and (2).

$$E_{Tx}(l,r) = E_{Tx-elec}(l) + E_{Tx-amp}(l,r) \tag{1}$$

$$= \begin{cases} l E_{elec} + l \epsilon_{fs} r^2 & , r < d_0 \\ l E_{elec} + l \epsilon_{fs} r^4 & , r > d_0 \end{cases} \tag{2}$$

where E_{elec} is the energy dissipated in operating the transmitter, r is the radius of the cluster and $\epsilon_{fs} r^2$ is the energy dissipated by transmitter amplifier which varies with distance r between the two nodes.

And to receive the l -bit message, the power consumption is given by eqn.(3)

$$E_{Rx}(l) = l E_{elec} \tag{3}$$

System Architecture

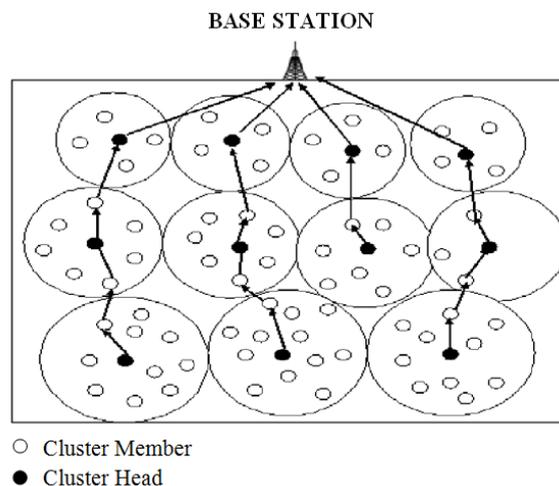


Fig 1. System Architecture

Fig. 1. Shows the proposed system architecture. It contains a single base station and a number of sensors. The sensors are organized into clusters and each cluster has a cluster head. It is a layered approach and the clusters in layer1 forms group1 and clusters in layer2 forms group2 and so on.

A. EECRA Algorithm

The purpose of this algorithm is to generate balanced clusters in energy level. Since the clusters near the base station forwards the data from many farther clusters. So their energy can be depleted quickly. In order to solve this issue and increase the network lifetime, the radius of the cluster is gradually increased. Depending upon the distance from the base station the radius of the cluster is determined. Fig1. Shows that the radiuses of further clusters are larger than the previous level clusters. EECRA can be divided into 4 steps.

1. Initialization

The N-sensor nodes are randomly deployed in a square field M*M.

2. Clustering

To form the first level clusters, Base station broadcasts the Hello message to a set of sensors N_s. The response message from sensors includes (ID, position, distance). Then the base station elects an optimum node as cluster head (CH) from N_s. The CH will broadcast the advertisement message to the non CH nodes. After that each non-CH node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement. After each node has decided to which cluster it belongs, it sends a join_req message to CH. The CH checks whether the node comes within the radius of the cluster. If so it sends a accept_req to the node and makes it as a member of that cluster.

Each member node of the cluster maintains a table called node table which contains ID of the node (NID), ID of the CH (HID), hop distance to the CH (HD), and ID of the intermediary node (SID). Each CH maintains a table called cluster head table which contains its own head ID (HID), all member node IDs (NID), ID of the intermediary node (SID), hop distance (HD) and the ID of other cluster heads. For the next level clusters the radius can be calculated by incrementing radius of first level cluster by 2. Fig 2 shows the clustering process.

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N → Total number of sensors.
1  BS → N sensor nodes: Requesting node's position and energy level
2  N sensor nodes → BS: Return (ID, position, distance, energy) to BS
3  Radius of first level cluster = transmission_range_sensor/2
4  F or any u ∈ Ns
    If (distance == radius)
        Select u as cluster head CH.
        //break the ties by selecting node with lower ID as CH
5  Broadcast hello message by node u
    // Sv is the set of nodes received the broadcast message
    for each v ∈ Sv
        find distanceutov
        check if (distanceutov ≤ radius)
            accept the node
        else
            reject the node
6  For the next level clusters consider the
    radius =(transmission_range_sensor/2)+i, i=2,4,.. and repeat steps 4&5.
    
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Fig. 2. Clustering

3. Cluster Head Selection

Once all the nodes are organized into clusters, the center of the cluster is identified. The nodes near the center are taken into consideration for cluster head selection. Among several nodes the node u which has high connection density and max residual energy is selected as CH. When the energy of CH reaches some threshold T, the next optimum node is selected as CH.

Neighbors of u are determined by eqn. $N(u) = \{v \in V | v \neq u \text{ and } d(u, v) \leq r\}$ (4)

Where d(u,v) is the distance between node u and v, r is the radius of the cluster.

Connection density D(u) is given by eqn.(5)

$$D(u) = \frac{\sum_1^{N(u)} [(u, v) \in E / v \in N(u)]}{|N(u)|} \tag{5}$$

Where |N(u)| is the number of neighbors of node u.

Weight of the node W(u) is given by eqn. (6)

$$W(u) = P[D(u)] + P[Re(u)] \tag{6}$$

Where R_e(u) is the residual energy of node u. It is determined by eqn.(7)

$$R_e(u) = I_e(u) - (E_{Tx} + E_{Rx}) \tag{7}$$

I_e(u) is the initial energy of node u.

E_{TX} is the energy required for transmission and E_{RX} is the energy required for reception. Fig 3 shows the pseudo code for cluster head selection.

1. Identify the centre of the cluster.
2. Consider the nodes near the centre and treat them as candidate Cluster Heads.
3. Calculate weight of the candidate cluster heads
4. $Weight_u = Residual\ Energy_u + Connection\ density_u$
5. Cluster Head \leftarrow a node with higher weight
6. Broadcast join req by u to all nodes.
7. Accept the reply req only when distance $u_{to v} \leq radius$.

Fig. 3. Cluster head selection

4. Data aggregation

Data aggregation is the process of acquiring the information from the sensors. Cluster Head prepares a TDMA slot for a subset of its members and collects data according to that. During next round CH selects another set of members and collects data from them. Since sensors data are spatially and temporally correlated. It then unicasts the data to the previous level CH that will forward the data to the Base station. In between if any cluster member detects any significant event that will be immediately notified to the stationary CH. Fig 4 shows the pseudo code for data aggregation.

1. CH prepares TDMA slot for a subset of its members and collects data according to it.
2. Checks the similarity of data and finds the mean value.
3. Construct a minimum spanning tree among the cluster heads.
4. Pass the mean value via shortest path to sink.
5. During next round select another subset of members.

Fig. 4 Data Aggregation

The energy consumed by the cluster head for aggregating the data is given by eqn. (8)

$$E_{CH} = (n-1) (lE_{elec} + l\epsilon_{fs}r^2) + (n-1) \{l * (E_{elec} * E_{DA})\} \quad (8)$$

Where n is the number of nodes in the cluster, E_{DA} is the energy required for data aggregation at a single node.

IV. PERFORMANCE ANALYSIS

In this section we evaluate the performance of our protocol using NS2. We simulated this EECRA against KMeans. 50 nodes were deployed in 500m*500m randomly. The initial energy of nodes=100J, E_{elec} =50nJ/bit, E_{DA} =5nJ/bit and ϵ_{fs} = 10pJ/bit are assumed in the simulation of our proposed system. In the experiment the number of clusters is set between 4 and 6.

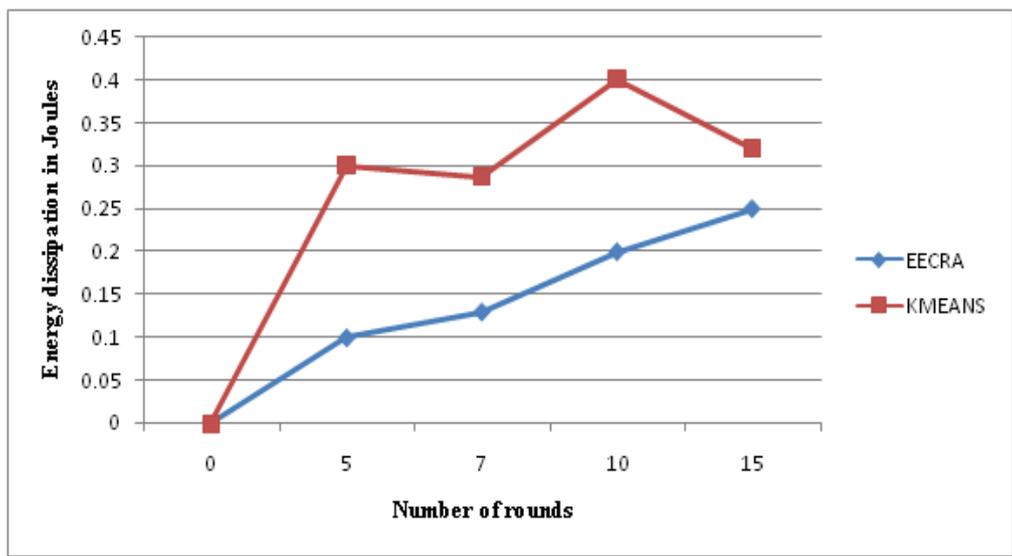


Fig 4. Energy dissipation of the network

From fig 5. It is observed that the energy dissipation is less in EECRA than K Means algorithm. The energy consumption is gradually increased when the number of nodes increases. This is because the balanced cluster organization. Whereas in K means, it does clustering and re clustering so the energy consumption is high. Lifetime of the network depends on the nodes residual energy. Fig 6 shows the residual energy of the network when the number of rounds increases.

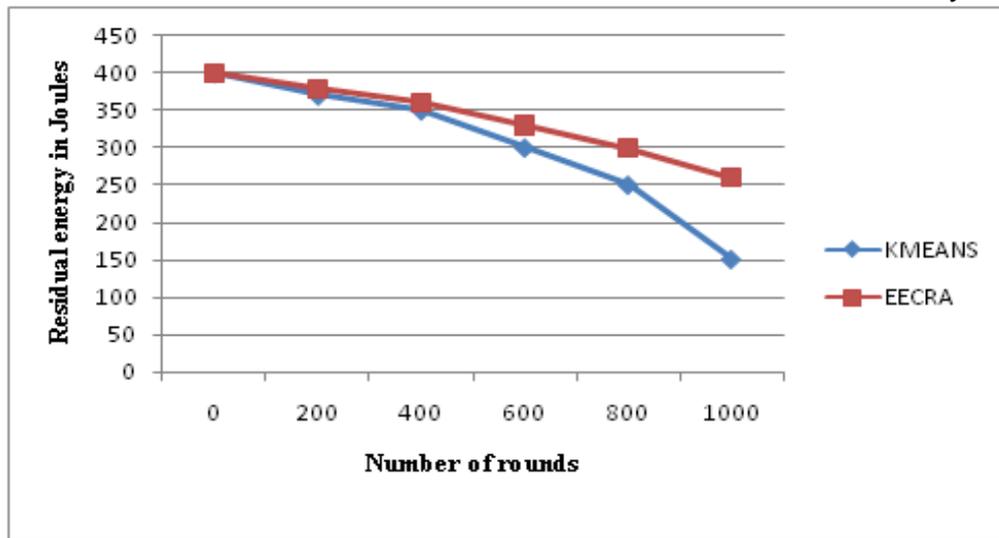


Fig.6. Residual energy of the network

V. CONCLUSION

Energy efficiency is a very important issue in wireless sensor networks. Energy efficiency of clustering based schemes for wireless sensor networks depends upon cluster head selection and suitable aggregation. In this paper we have presented an efficient cluster head selection scheme that makes network function for a longer time period. The proposed architecture gradually increases the radius of the cluster in order to balance the energy. Since clusters near the base station forwards the data of many clusters which are far away. Cluster head selection is restricted to nodes near the centre of the cluster only. With random data collection the amount of data transmission also getting reduced. Simulation results show that the proposed scheme works better and increases network life time.

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