International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 08 | Aug -2016 www.irjet.net p-ISSN: 2395-0072

Efficient Cluster Head Selection Method Based On K-means Algorithm to Maximize Energy of Wireless Sensor Networks

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Abstract - *Wireless Sensor nodes have very less processing capability and battery power thus energy efficiency is the primary issue in maintaining network. The proposed work uses K-means algorithm which forms the clusters of nodes based on Euclidian distances between them. If the value of the node is less than threshold value, then that node is selected as Cluster Head (CH). The paper is based on the concept of finding cluster head to maximize the energy of Wireless Sensor Network (WSN).This helps the network to balance energy consumption by letting all the nodes to be selected as CH.*

Key Words*: *Wireless Sensor Network, Energy Efficiency, Cluster head selection, k -means Algorithm, Clustering

1. INTRODUCTION

Wireless sensor network (WSN) are composed of independent sensor nodes deployed in an area working collectively in order to monitor different environmental and physical conditions such as motion, temperature, pressure, vibration, sound or pollutants. The main reason in the advancement of wireless sensor network was military application in battlefields in the beginning but now the application area is extended to other fields including monitoring, controlling of traffic and health monitoring [1]. There are different constraints such as size and cost results in constraints of energy, bandwidth, memory and computational speed of sensor nodes. Deployment of sensor nodes in an area for collection of data is a typical application of WSN.

Sensor node are densely deployed in WSN that means physical environment would produce very similar data in close by sensor node and transmitting such type of data is more or less redundant. So all these facts encourage using of sensor nodes such that group of sensor node can be combined or compress data together and transmit only compact data. This grouping process of sensor nodes in a densely deployed large scale node is known as clustering. The way of combining and compressing data belonging to a single cluster is called Data fusion or data aggression [1] [2].

A cluster-head selection is done by modifying the probability of each node to become cluster-head based on remaining energy level of sensor nodes for transmission [3], [4]. An improved Low-Energy Adaptive Clustering Hierarchy LEACH based on cluster head multi-hops algorithm, and considered the premise of node energy, the optimum number of cluster head and selecting cluster node, and through the use of limiter the number of nodes in each cluster to balance the energy depletion of each node [5]. A new threshold assignment for Low-Energy Adaptive Clustering Hierarchy LEACH that improves energy consumption and insertion of the distances of nodes from BS in threshold assignment is done in order to unbalance the CH selection to reduce energy consumption in the network [6]. PEACH (Proxy-Enabled Adaptive Clustering Hierarchy) is a protocol that improves LEACH in terms of network lifetime. This is achieved by selecting a proxy node which can assume the role of the current cluster-head of weak power during one round of communication. PEACH is based on the consensus of healthy nodes for the detection and manipulation of failure in any cluster-head. It allows considerable improvement in the network lifetime by reducing the overhead of re-clustering [7]. There is another approach known as energy-driven adaptive clustering hierarchy (EDACH) which puts more number of cluster-heads in the region relatively far from the base station. The number of member nodes in their clusters will then be smaller than that of other clusters. This compensates the larger energy consumption due to larger distance to the base station [8].

In this paper we propose a new CH selection method to form energy efficient WSN. As compared to random probabilistic method of LEACH and its limitations, here we use deterministic method of K-Means algorithm. The K - means algorithm forms the clusters such that the distances between the nodes and the CH become minimal. The proposed approach thus allows minimizing energy consumed for the sensor nodes to send the data to the CH in their cluster, thus resulting in an efficient network by adaptively selecting a node as cluster head whose value is less than threshold value.

The rest of this paper is arranged as follows. Section 1 is Proposed Scheme, section 2 is result analysis and evaluation

2. PROPOSED SCHEME

2.1 Network Model

In the proposed scheme the WSN is assumed to have the following features:

- A homogeneous wireless sensor network is assumed to be the network model where nodes are randomly dispersed throughout the sensor field.
- Base station has no restriction on energy constraint and is aware of the geographical locations of the nodes.
- Each node has an ID number.
- All nodes are fixed or pseudo-static.
- All nodes are able to send the data to the BS.
- All nodes are able to control their energy consumption.

Table- 1: Wsn parameters

Parameter	Value
Size Of the Network	200*200
Initial Energy of nodes	200
Free Space Energy For Transmission Of data packet (єfs)	10pj/bit/m^2
Multipath Energy For Transmission Of data packet (єmp)	0.0013pj/bit/m^2
Distance for transmitting data packet (do)	88m
Energy for transmission of data packet (Eelec)	50nj/bit
Energy For aggregation Of data (EDA)	5nj/bit
Location Of Base Station	0,0
Size Of the data packet	500 byte

2.2 K-means clustering algorithm

The proposed scheme uses K-means algorithm which forms the clusters of the nodes in the network based on the Euclidean distances between them. Here 200 nodes are divided into 4 clusters. The proposed cluster head selection scheme consists of three steps as follows.

Step 1: Initial Clustering

Assume that the WSN of n nodes is divided into k clusters. First, k out of n nodes are randomly selected as the CHs. Each of the remaining nodes decides its CH nearest to it according to the Euclidean distance.

X1 = (x11; x12: x1n)

X2 = (x21; x22: x2n)

$$\text{Distance}(X1i, X2i) = (X1i - X2i)^2 \qquad [1]$$

Step 2: Reclustering

Once each of the nodes in the network is assigned to one of k clusters, the centroid of each cluster is calculated as follows.

$$centroid(x,y) = \frac{1}{n}\sum_{i=1}^{n} xi, \frac{1}{n}\sum_{i=1}^{n} yi \qquad [2]$$

Where,

n = number of nodes

x and y = co-ordinates of the nodes

Step 3: Choosing the CH

After the clusters are formed, an ID number is assigned to each node of a cluster according to the distance from the centroid, assigning smaller number to the closer one .every node has assigned values from 1 to 200. Node which is nearest to centroid and whose energy is above threshold will be selected as CH. Threshold Value can be calculated as follows.

$$T(n) = \frac{p}{1-p(r\,mod\,1/p)} \frac{Eresidual}{Einitial} kop \qquad [3]$$

Where,

p = Percentage of the number of CHs out of the total number of nodes.

r = Current round.

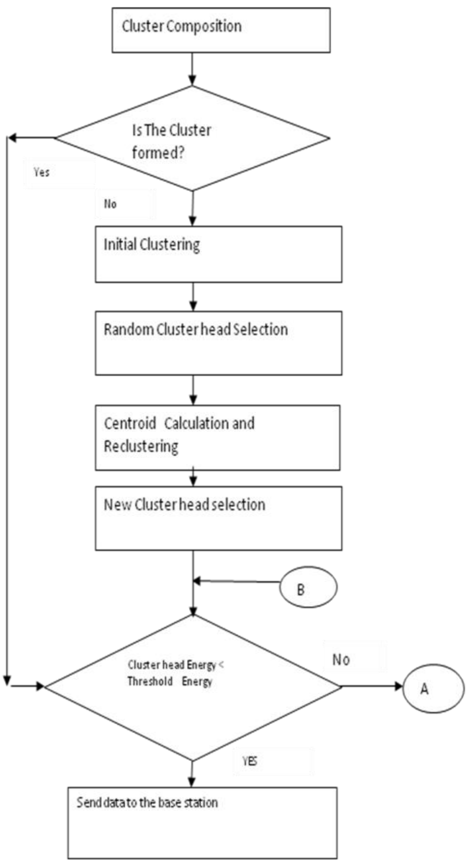
$E_{residual}$ = Remaining energy of the node and

$E_{Initial:}$ energy of the node before the transmission.

Step 4: Residual Energy and Density Checking along with Node ID

The remaining energy of the CH is checked every round to maintain the connectivity of the network. Nodes are given random values between 0 and 1. If randomly given value of sensor node is smaller than the T (n) threshold [9] and then the node in the next order is selected as a new CH.

Flow Chart of Proposed Scheme



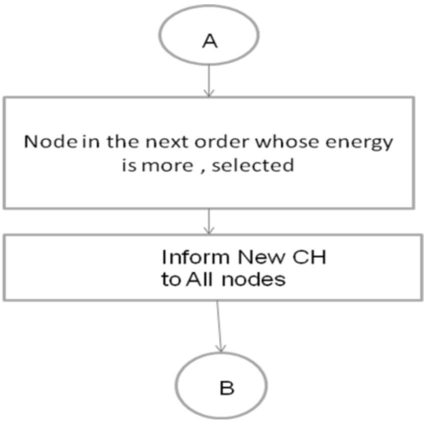


Figure 1. Flow chart of proposed scheme

3. Clustering of deployment sensors:

For clustering of nodes the k- means clustering algorithm is used, which divides the n number of nodes into the k-clusters. Here we are using 4 clusters that are shown by different colors. For the clustering algorithm we need the set of observations (x1, x2 …xn) and also we choose randomly the value for k, where the k < n. In the k-means clustering algorithm the resulting clusters intra cluster similarity is high as compared to inter cluster similarity. K-means algorithm follows following steps:

1. Randomly generate k points (cluster centers), k being the number of clusters desired.
2. Calculate the Euclidian distance between each of the data points to each of the centers, and assign each point to the closest center.
3. Recalculate the new cluster center by calculating the mean value of all data Points in the respective cluster.
4. Now with the new centers, repeat step 2. If the cluster assigned for the data points changes, repeat step 2 & 3, otherwise stop the process.

Distance (X1i, X2i) = $(X1i-X2i)^2$ [4]

4. Energy Consumption Model:

For calculating energy dissipated during transmission and reception of the packet both free space and multipath propagations are used.

Energy Dissipation in Non–CH and CH: Non-CH nodes transmit their data to CH.CH receives data from the Non-CH and transmits aggregated data to the base station. Energy dissipation in CH and Non-CH can be calculated as

$$ETX (K, d) = KEelec+K\epsilon fsd^2, \text{ if } d<d0 \quad [5]$$

$$= KEelec+K\epsilon mpd^2, \text{ if } d>d0 \quad [6]$$

Here *Eelec* is the energy required for processing 1-bit data with the electronic circuits. *εfs* and *εmp* is the energy taken for transmitting 1-bit data to achieve an acceptable bit error rate in the case of free space model and multipath model, respectively. They are dependent on the distance of transmission. Note that energy dissipation of free space and multipath is proportional to *d2* and *d4*, respectively. The threshold, *d0*, is calculated as

$$d0=\sqrt{\epsilon fs/\epsilon mp} \quad [7]$$

The energy taken to receive a *k*-bit message is calculated by Eq. (8).

$$ERX (K, d) = KEelec \quad [8]$$

5. Performance Evaluation and Result Analysis

The proposed scheme is evaluated by using MATLAB R2013 (b). In this we consider a network consisting of 200 sensor nodes which are randomly distributed in the field of 200m×200m. The performance of the system after 25 and 50 rounds is displayed in Figure 2 and Figure 3. Residual Energy of the network after 25 rounds is 397.566 Joules and cluster head energy is 6.875 Joules. Residual Energy of the network after 50 rounds is 395.11 Joules and cluster head energy is 7.854 Joules. After every 50 rounds new cluster heads are selected to balance total energy of the network as shown in the Figure 4.

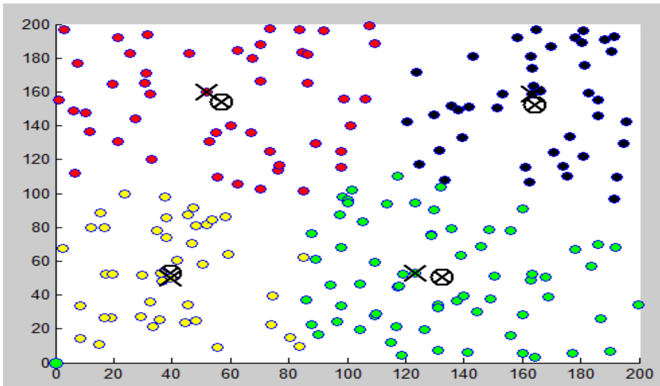
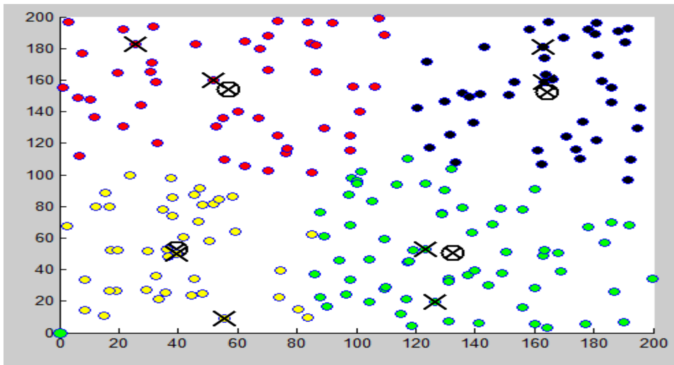


Figure 2. Number of rounds =25, number of cluster heads = 4, number of centroids = 4, Threshold value = 0.025 and with initial cluster heads.



Fi gure 3. **Number of rounds =50, number of cluster heads = 4, number of centroids = 4, Threshold value = 0.02 and initial and new cluster heads.**

When all the nodes in the wireless sensor network run out of energy it is called as Network lifetime .Figure 4 shows remaining energy of node after each round. From this figure we can see that after 2000 rounds, there is still sufficient amount of energy in the network.

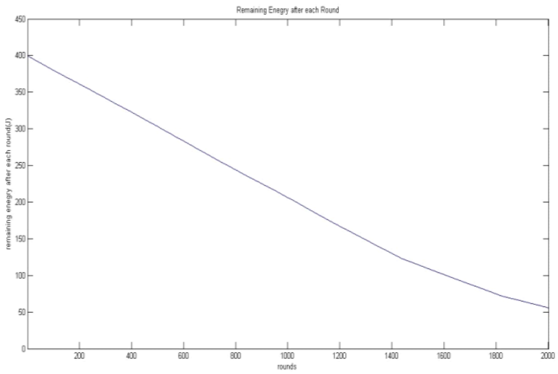


Figure 4. Remaining Energy of a WSN after each round

The Figure5 shows energy consumption in the cluster head as round proceeds. Cluster head consumes large amount of energy as compared to sensor nodes in the network.

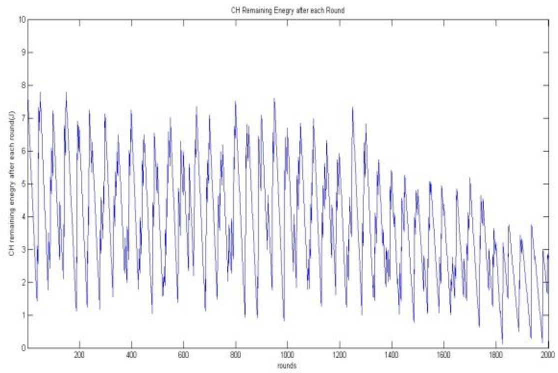


Figure 5: Cluster head remaining Energy after each round

The number of alive nodes is also an important parameter to evaluate the lifetime of a network. The numbers of alive nodes are checked after each round. Figure 6 shows that more than half of nodes are still alive after 2000 rounds.

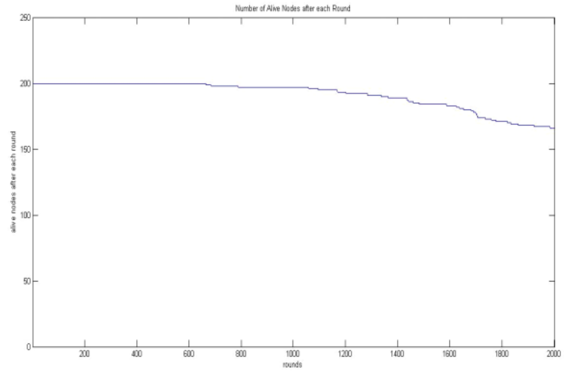


Figure 6. Number of alive nodes after each round

From the reference to base paper [3] and Table 2 it can be shown that proposed scheme is better in terms of remaining energy, number of alive nodes and Cluster head remaining energy of an existing scheme that is LEACH protocol.

Table 2- Comparison of parameters leach and k-means

Cluster head selection method/protocol	Residual Energy of network	Residual energy of Cluster head nodes	Number of alive nodes
Leach	Very little energy is left after 1000 rounds	The average energy consumption of the CH nodes is 0.262J for 10 rounds	After 1000 rounds no live node is left
K-means	After 2000 rounds still has some energy is left in the network	The average energy consumption of the CH nodes is 0.019J for 10 rounds	After 2000 rounds 50 nodes are still alive

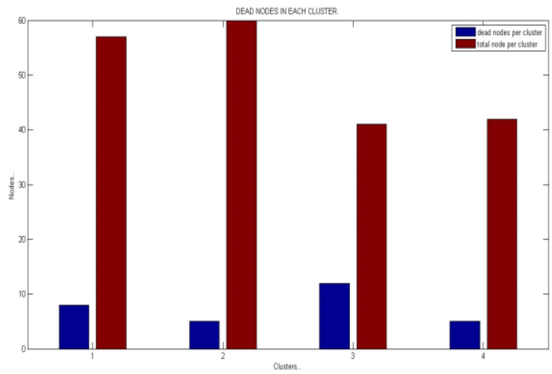


Figure 7. Graph of number of dead nodes verses total number of nodes in each cluster.

The Figure 6 shows number of dead nodes and total number of nodes in each cluster.

CONCLUSIONS

This paper examines an improved CH selection method using K-means algorithm for energy-efficient wireless sensor network. It is based on finding the CH of the minimum distance from the centroid according to the Euclidean distance. Due to effective selection of the CHs the overall efficiency of the wireless sensor network is improved in terms of energy and number of alive nodes. The results show that performance of the proposed scheme is superior to the LEACH protocol in terms of network life time and energy efficiency.

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