Distance based Cluster Head Selection Algorithm for Wireless Sensor Network

Bhawnesh Kumar
Department of Computer Science & Engineering
Mewar University
Rajasthan, India

Vinit Kumar Sharma
Department of Computer Science & Engineering
Shamli Institute of Engineering & Technology,
Shamli, U.P., India

ABSTRACT
In this paper, a distance based Cluster head selection algorithm is proposed for improving the sensor network life time. This protocol achieves a good performance in terms of lifetime by balancing the energy load among all the nodes. This clustering technique help to prolong the life of wireless sensor network, especially in hostile environment where battery replacement of individual sensor nodes is not possible after their deployment in the given target area. Therefore, the proposed technique to distribute the role of the cluster head (CH) among the wireless sensor nodes in the same cluster is vital to increase the lifetime of the network. This algorithm uses a distance based method for providing the cluster head selection. Clustering techniques also provide good load balancing, and in-network data aggregation.

Keywords
Sensor Networks, Clustering, Network life Time, Energy Efficiency, Data Aggregation

1. INTRODUCTION
The continuous enhancement in communication, computation and hardware technologies enable new devices known as sensor nodes [1]. Wireless Sensor Networks (WSNs) are formed by hundreds or thousands of nodes that gather information and forward it to a sink node. These large numbers of nodes, which have the ability to communicate wirelessly, to perform limited computation, and to sense their surroundings, form the WSN [2]. Specific functions can be obtained through cooperation between these nodes; functions such as sensing, tracking, and alerting [3]. These functions make these wireless sensors very useful for monitoring natural phenomena, environmental changes, controlling security, estimating traffic flows, monitoring military application, and tracking friendly forces in the battlefields [2]. We consider a network of energy-constrained sensors that are deployed over a geographic area for monitoring the environment. Among the sources of energy consumption in a sensor node, wireless data transmission is the most critical.

Obviously, WSNs need to be stable in design and structure to transfer data among the wireless sensors safely and without any problems, because of their use in critical areas and real time systems. Moreover, consuming less energy and increasing the lifetime of the wireless sensor nodes are the main objectives in designing the WSN, because of the limitation of the power resources and the difficulties of replacing the batteries of the wireless sensors.

Wireless Sensor Networks present vast challenges in terms of implementation. There are several key attributes that designers must carefully consider, which are of particular importance in wireless sensor networks.

- Cost of nested clustering
- Selection of Cluster heads and sub cluster heads
- Synchronization
- Data Aggregation
- Repair Mechanisms
- Quality of Service (QoS)

2. CLUSTERING
Cluster may be defined as follows:
Definition: Dividing the sensor networks into small manageable units is called as clustering & process known as clustering process. Though the main reason behind the implementation of the clustering approach is to improve the scalability of the network (prolong), it is an important factor in achieving energy efficient routing of data within the network [12].

Study on energy efficient routing in WSN brings this two broad classification of approaches. They are,

- Clustering approach
- Tree based approach

In a wireless sensor network, cluster is a group of sensor nodes in which one node will act as a cluster head (CH) [9, 10], and remaining nodes will act as member nodes. Clustering helps in reducing the number of exchanged communications in wireless sensor network resulting in low consumption of battery power of individual sensor nodes. This increases the life span of the wireless sensor network.

A cluster head is selected for each cluster based on the energy level of that node or distance based also. The main objective is to make only the cluster head communicate with the base station so that the remaining node can be put to a sleep state.

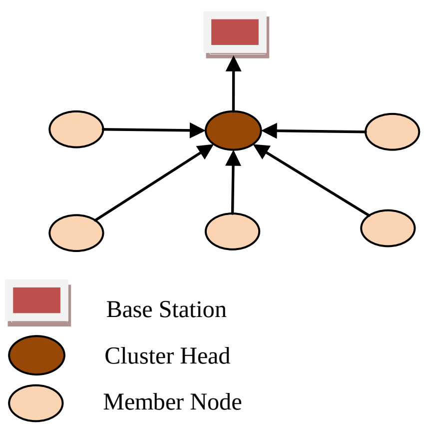

Fig. 1 Cluster head model in WSNs

3. RELATED WORK

Many greedy algorithms have been proposed to choose cluster heads in ad hoc networks, and wireless sensor networks. They are based on the criteria of highest degree, lowest- ID, highest-ID, and node-weight, residual energy, probability, and any combination of these. The clustering techniques can also be classified based on cluster size, namely Single hop, and Multi-hop. LEACH [6] (Low-Energy Adaptive Clustering Hierarchy) elects cluster heads based on randomly generated value between 0 and 1. If this randomly generated value is less than threshold value then the node becomes cluster head for the current round. LEACH [11] is the first hierarchical cluster-based routing protocol for wireless sensor network which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access). Remaining nodes are cluster members. PEGASIS (power-efficient gathering in sensor information systems) [4],[5] is an improvement over LEACH by making only one node transmit data to the base station in this protocol every node transmits it's data only to its nearest/neighbor node in the data fusion phase. PEGASIS starts with the farthest node from the base station. HEED (Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-Efficient Approach) [7] periodically selects cluster heads according to a combination of their residual energy, and communication cost. Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC) [8] is modified version of the HEED. It claims to provide more balanced cluster size and intra cluster topology. HEED uses two clustering parameter to select CH: one is residual energy, and the other is communication cost. The communication cost is defined as an average minimum reach ability power, which means the minimum power levels required by all nodes within the cluster range to reach the CH. The communication cost held by CHs is used to let a node which belong to several CHs choose the best one.

In HEED, each node must be mapped to exactly one cluster, and each node belongs to its only CH within one hop. After a clustering process, each node can either elect to become a CH due to a probability or join a cluster according to CH messages.

Sensors measure real-world conditions, such as heat or light, and then convert this condition into an analogue or digital representation.

To select a cluster head following steps are followed:

- Placing sensor node
- Clustering process
- Selecting cluster head
- Remaining nodes select as child node
- Sensing information from child nodes & sends to the corresponding cluster head
- Transferring information to base station

4. PROPOSED WORK

In WSN after creating the clusters we have to decide the cluster head .Here we propose an algorithm for selecting cluster head based on distance

4.1 Proposed algorithm

Perform these steps for each & every cluster.

SELECT_CLUSTERHEAD (n, S)

Begin:

Step1. Let we have a set S of n nodes in a cluster viz.

$S= \{S_1, S_2, S_3\ldots S_n\}$

Step2. Calculate the distance of one node to all nodes.

for i=1 to n do
    for j=1 to n do
        d_{ij} = distance from s_i to s_j
    endfor
endfor

Step3. Calculate the sum of all distance from one to all nodes.

for i=1 to n do
    for j=1 to n do
        $D_i=D_i + d_{ij}$
    endfor
endfor

Step4. Calculate distance from BS to each node for all nodes.

for i=1 to n do
    DBS_i = Distance from BS to S_i
endfor

Step5. Calculate the net distance with base station for each node

for i =1 to n do
    $NDBS_i=DBS_i + D_i$
endfor

Step6. Select the cluster head based on all NDBS values.

$NDBS_i = \text{Min} (NDBS_1, NDBS_2, NDBS_3, NDBS_4\ldots NDBS_n)$

And corresponding node will selected as cluster head.

End.

4.2 Matrix Representation

Step 1: Let we have a set S of n nodes in a cluster viz. $S= \{S_1, S_2, S_3\ldots S_n\}$ and let the distance from each node to all other nodes within cluster can be represented as

Step 2: Let the sum of all distances from a single node to all other nodes are represented as

d(1,1) → Distance between S_1 to S_1
d(1,2) → Distance between S_1 to S_2
…………
d(1,n) → Distance between S_1 to S_n

d(2,1) → Distance between S_2 to S_1
d(2,2) → Distance between S_2 to S_2
…………
D(2,n) → Distance between S_2 to S_n
……………
…………..
d(i,j) → Distance between S_i to S_j
……………
…………
D(n,1) → Distance between S_n to S_1
D(n,2) → Distance between S_n to S_2
………
D(n,n) → Distance between S_n to S_n

Distance matrix representation from one node to other node in algorithm.

$$\begin{bmatrix} d(1,1)d(1,2)d(1,3)d(1,4) & \cdots & d(1,n) \\ d(2,1)d(2,2)d(2,3)d(2,4) & \dots & d(2,n) \\ \vdots & \ddots & \vdots \\ \vdots & \ddots & \vdots \\ d(n,1)d(n,2)d(n,3)d(n,4) & \cdots & d(n,n) \end{bmatrix}$$

Step3: Add all distance from one node to all other nodes. Find the value of D(i).

$$D(1) = d(1,1) + d(1,2) + d(1,3) + d(1,4) + \cdots d(1,n)$$
$$D(2) = d(2,1) + d(2,2) + d(2,3) + d(2,4) + \cdots d(2,n)$$
$$D(3) = d(3,1) + d(3,2) + d(3,3) + d(3,4) + \cdots d(3,n)$$
……
……
$$D(i) = d(i,1) + d(i,2) + d(i,3) + d(i,4) + \cdots d(i,n), \quad 1 \le i \le n$$
…….
…….
$$D(n) = d(n,1) + d(n,2) + d(n,3) + d(n,4) + \cdots d(n,n)$$

Calculate the distance vector for each node representation of step 3 in algorithm.

$$\begin{bmatrix} D(1) \\ D(2) \\ D(3) \\ D(4) \\ \vdots \\ \vdots \\ \vdots \\ D(n) \end{bmatrix} = \begin{bmatrix} d(1,1) + d(1,2) + d(1,3) + d(1,4) & \cdots & d(1,n) \\ d(2,1) + d(2,2) + d(2,3) + d(2,4) & \cdots & d(2,n) \\ d(3,1) + d(3,2) + d(3,3) + d(3,4) & \cdots & d(3,n) \\ d(4,1) + d(4,2) + d(4,3) + d(4,4) & \cdots & d(4,n) \\ \vdots & \ddots & \vdots \\ \vdots & \ddots & \vdots \\ \vdots & \ddots & \vdots \\ d(n,1) + d(n,2) + d(n,3) + d(n,4) & \cdots & d(n,n) \end{bmatrix}$$

Step4: Now the distance from base station (DBS) to each node, respectively

DBS(1) = Distance between BS to S_1
DBS(2) = Distance between BS to S_2
DBS(3) = Distance between BS to S_3
………..
………..
………..
………..
DBS(n) = Distance between BS to S_n

Distance from base station DBS(i), where $1 \le i \le n$, vector representation to all nodes of step 4 in algorithm.

$$\begin{bmatrix} DBS(1) \\ DBS(2) \\ DBS(3) \\ DBS(4) \\ \vdots \\ \vdots \\ \vdots \\ DBS(n) \end{bmatrix} = \begin{bmatrix} Distance\ between\ S(1) and\ BS \\ Distance\ between\ S(2) and\ BS \\ Distance\ between\ S(3) and\ BS \\ Distance\ between\ S(4) and\ BS \\ \vdots \\ \vdots \\ \vdots \\ Distance\ between\ S(n) and\ BS \end{bmatrix}$$

Step5: Now the net distance with base station (NDBS)

Calculate the net distance with base station NDBSi, where $1 \le i \le n$, vector for each node representation of step 5 in algorithm.

$$\begin{bmatrix} NDBS(1) \\ NDBS(2) \\ NDBS(3) \\ NDBS(4) \\ \vdots \\ \vdots \\ \vdots \\ NDBS(n) \end{bmatrix} = \begin{bmatrix} D(1) \\ D(2) \\ D(3) \\ D(4) \\ \vdots \\ \vdots \\ \vdots \\ D(n) \end{bmatrix} + \begin{bmatrix} DBS(1) \\ DBS(2) \\ DBS(3) \\ DBS(4) \\ \vdots \\ \vdots \\ \vdots \\ DBS(n) \end{bmatrix}$$

Step6: Select the cluster head

NDBS(i)=Min (NDBS(1), NDBS(2), NDBS(3), NDBS(4)… NDBS(n))

After performing all steps in above mentioned sequence, we found that node S(i) has smallest distance in comparison to other nodes. So, we can conclude that if node S(i) is selected as a cluster head, node S(i) will consume less energy in comparison of other node.

5. SIMULATION

The proposed algorithm is successfully implemented in MATLAB 7.0. Fig. 2, shows the set of input and output. In order to perform the computation through MATLAB program, firstly the total number of nodes of a cluster and their corresponding ID of each node are entered. Then distance between each pair of node is entered, which generates the distance matrix of cluster. Then the net distance (by adding the distance from each node to other connected nodes say D(i)) is computed. And then the distance DBS (i) from base station (BS) to each node of cluster is entered. By adding the computed distance vectors D(i) and DBS(i), net distance with base station vector (NDBS(i)) is computed and the node with minimum NDBS(i) value is chosen as cluster head. And then the distance based on cluster head selection is computed. And the corresponding energies of nodes are computed with the below mwntioned equation.

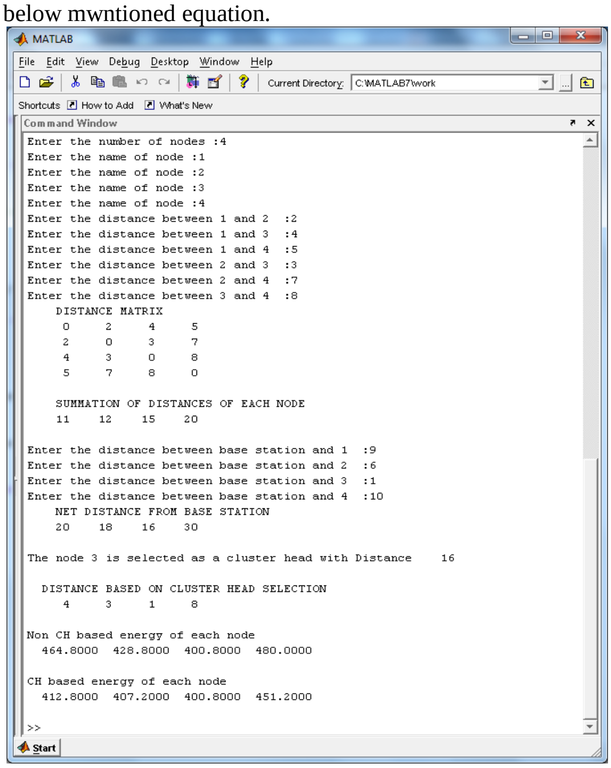

Fig 2: Implementation of proposed algorithm

In the implementation of proposed algorithm, a cluster of four nodes are considered viz. 1, 2, 3 & 4 and a base station BS shown in Fig. 3 is considered and the node which have minimum net distance (calculated according to proposed algorithm), elected as a cluster head.

Firstly, a cluster of nodes are plotted in MATLAB 7.0 as shown in Fig. 3. Fig.3, also represents the nodes of a cluster, depicts the distance between each nodes of a cluster and the distance of each node from base station (BS).

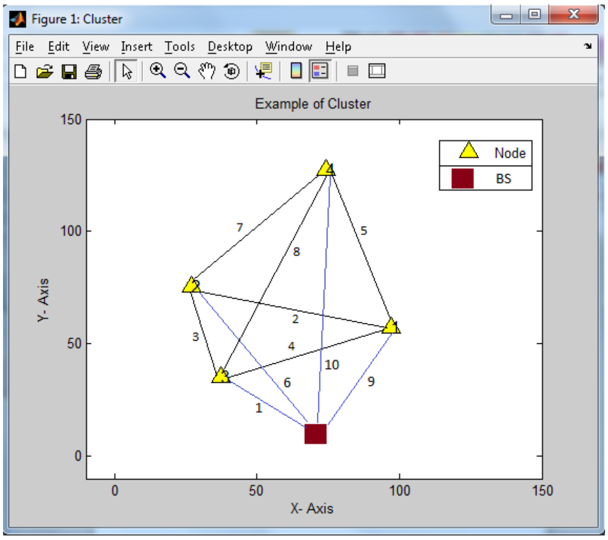

Fig 3: Scattered node of a cluster with in-between distance

After plotting a cluster of nodes in MATLAB 7.0 all matrix calculations are performed, node is chosen as a cluster head. The energy is calculated on the basis of non-CH approach & proposed algorithm of each node.

Fig. 4 shows comparison, based on energy consumption between non-CH & proposed algorithm, Fig. 5 shows comparison, based on distance coverage between non-CH & proposed algorithm for each node.

To calculate the sending energy with using following formula:

$$E(t) = (E(elec) * k) + (E(amp) * k * d * d)$$

Table1. Radio Parameters

Parameter	Definition	Unit
E_{elec}	Energy dissipation rate to run the radio	50nJ / bit
ε_{amp}	Energy dissipation rate to run transmit amplifier	100 pJ / bit /m2
k	Data length	bit (8)
d	Node transmission Range	m

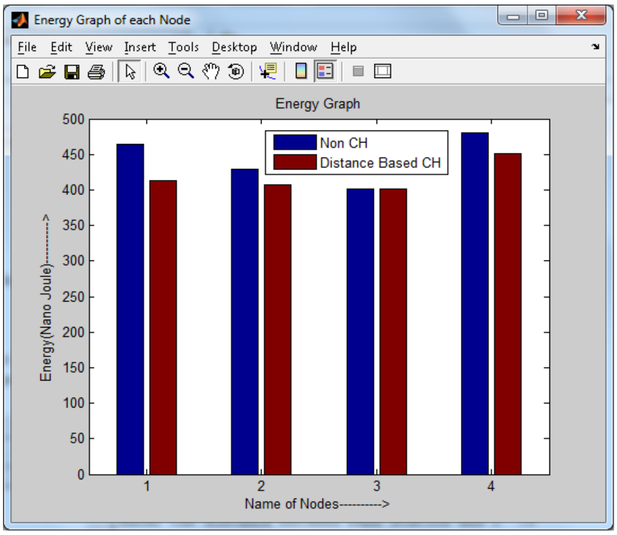

Fig 4: Energy Graph of each Node

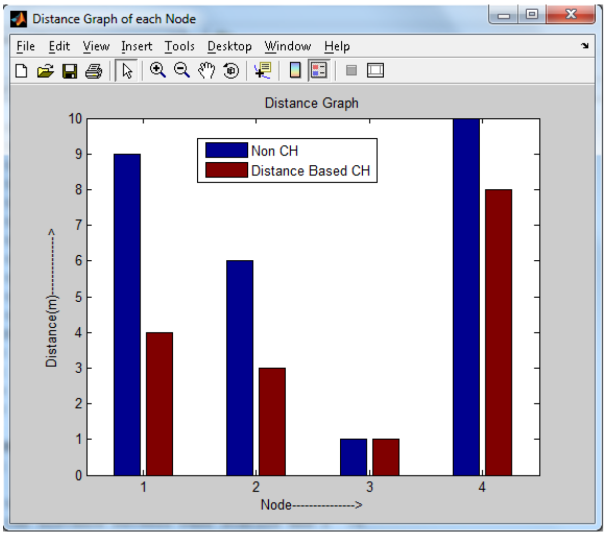

Fig 5: Distance Graph of each Node

6. CONCLUSION

In clustering hierarchy, the cluster head decision is a major challenge. If network is taken as a whole, then the power consumption can be optimized by the rotation of this cluster head inside the individual clusters. Energy conservation is a significant concern in the WSNs, especially as the energy conservation of the cluster head in the cluster-tree network has to be higher because of the different operations, which they control in the network. In this paper, a new technique is proposed to select cluster head among some of the wireless sensor nodes based on net distance with base station. The proposed technique aims to increase the lifetime of the whole network, and to increase the number of nodes, which will remain alive for the maximum period of time.

7. REFERENCES

[1] I. F. Akyildiz and W. Su and Y. Sankarasubramaniam and E. A. Cayirci A survey on sensor network, IEEE Communication Magazine 40, 8 (August 2004), 102-114.

[2] K. RÄomer, O. Kastin, F. Mattern. Middleware Challenges for Wireless Sensor Networks. ACM SIGMOBILE Mobile Computing and Communications Review, vol. 6, no. 4, pp. 59-61, 2002.

[3] R. Shorey, A. Ananda, W. T. Ooi. Mobile, Wireless, and Sensor Networks, 1st Edition, IEEE press, John Wiley & Sons, 2006.

[4] S. Lindsey, C. Raghavendra, and K. M. Sivalingam, "Data Gathering Algorithms in Sensor Networks Using Energy Metrics", IEEE Trans. Parallel and Distributed Systems, vol. 13, no. 9, pp. 924-935, Sep. 2002.

[5] S. Lindsey, and C. S. Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Information Systems", in Proc. Aerospace Conf. Los Angeles, 2002.

[6] V. Loscri, G. Morabito, and S. Marano, A Two-Level Hierarchy for Low- Energy Adaptive Clustering Hierarchy, DEIS Department, University of Calabria.

[7] O. Younis and S. Fahmy, HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks IEEE Transactions on Mobile Computing 3, 4 (October 2004), 366-379.

[8] P. Ding and J. Holliday and A. Celik, Distributed energy efficient hierarchical clustering for wireless sensor networks In Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems(DCOSS05) (Marina Del Rey, CA, june 2005).

[9] Thiemo Voigt, Adam Dunkels, Juan Alonso, Hartmut Ritter and Jochen Schiller. "Solar-aware Clustering in Wireless Sensor Networks", 2004.

[10] Dissertation, Hang Zhou, Zhe Jiang and Mo Xiaoyan, "Study and Design on Cluster Routing Protocols of Wireless Sensor Networks",2006.

[11] M. Bani Yassein, A. Al-zou'bi, Y. Khamayseh and W. Mardini, Improvement on LEACH Protocol of Wireless Sensor Network (VLEACH), In Proceedings of the International Journal of Digital Content Technology and its Applications Volume 3, Number 2, June 2009

[12] B.Baranidharan and B.Shanthi, A Survey on Energy Efficient Protocols for Wireless Sensor Networks, In Proceedings of the International Journal of Computer Applications (0975 – 8887) Volume 11– No.10, December 2010.