HIGHLY COMPETENT CLUSTERING MECHANISM FOR CONNECTING WIRELESS SENSOR NETWORK FIELDS

Dr. S.R.BOSELIN PRABHU, ** Dr. E.GAJENDRAN, * N.BALAKUMAR**

**Assistant Professor, Department of Electronics and Communication Engineering,*
SVS College of Engineering, Coimbatore, India
***Professor, Department of Information Technology,*
St.Martin's Engineering College, Hyderabad.
****Assistant Professor, Department of Electrical and Electronics Engineering,*
Tamilnadu College of Engineering, Coimbatore, Tamilnadu, India.

ABSTRACT

In this paper a highly competent distributed clustering mechanism, the hybrid energy efficient clustering algorithm (HEECA) for connecting wireless sensor network fields has been proposed, which mainly spotlights on reduction in energy utilization. It is a well distributed, energy efficient clustering algorithm which employs distributed relay nodes, adaptive transmission power and threshold-sensitive clustering mechanism for setting up the cluster. The proposed scheme is compared with the well-evaluated existing distributed clustering algorithms O-LEACH and HEED. Simulation results clearly depict an excellent advancement in remaining energy and throughput of the wireless sensor system. Simulation study also demonstrates an exceptional prolongation in network lifetime compared to the two existing clustering algorithms

***Keywords**: Wireless sensor network (WSN), distributed clustering, distributed relay node, adaptive transmission power, throughput, network lifetime.*

1. INTRODUCTION

Wireless Sensor Networks (WSN) finds applicable in many real-world applications (figure 1) like military, target tracking, environmental monitoring and civilian applications. The concerning protocols in WSNs can be classed into three major categories: routing protocols, sleep/awake scheduling protocols and clustering protocols [8]. One prime method to attain energy efficiency is to efficiently group the sensor nodes into clusters (figure 2), in order to trim down the energy consumption, the sensor nodes are clustered into a number of small groups called clusters. Each and every cluster has a leader which is branded as cluster-head (CH). Clustering may be centralized or distributed, based on the planning of CH. Distributed clustering mechanism is used for some exclusive reasons like sensor nodes prone to failure, better collection of data and minimizing redundant information. In this paper, a distributed clustering mechanism, Hybrid Energy Efficient Clustering Algorithm (HEECA) is proposed which is based on distributed relay nodes (DRN) for effectively connecting two WSN fields, adaptive transmission power for variable power usage for near/far located sensor nodes for cluster formation.

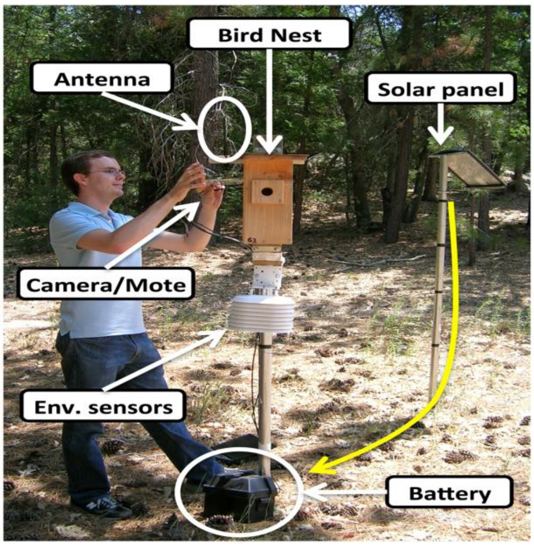

Figure 1: Application of WSN for environmental monitoring.

The prime objective of the proposed algorithm is to achieve energy efficiency and extended network lifetime when two far-away located WSN fields are needed to be effectively coupled together for cooperative communication. The performance of the proposed clustering algorithm is evaluated against the two well evaluated existing algorithms Optical Low Energy Adaptive Clustering Hierarchy (O-LEACH) [1] and Hybrid Energy Efficient Distributed Clustering (HEED) [2].

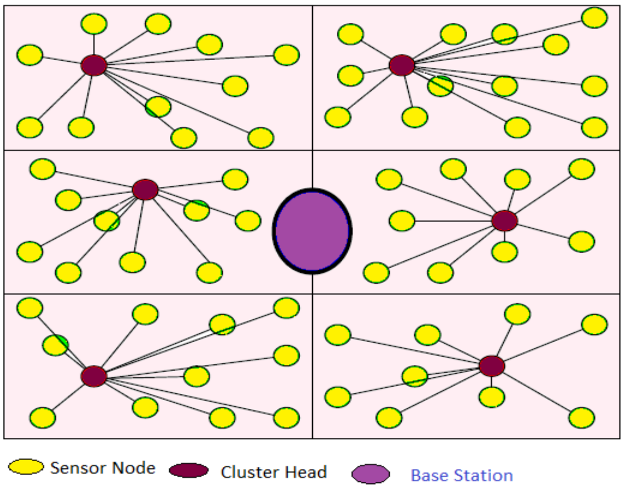

Figure 2: A method of cluster formation

2. REVIEW OF EXISTING DISTRIBUTED CLUSTERING ALGORITHMS

The algorithms described here are utterly distributed, diverging only in the methodology by which the CH is elected. Algorithm for Cluster Establishment (ACE) [3], Ring-structured Energy-efficient Clustering Architecture (RECA) [4], Low Energy Adaptive Clustering Hierarchy (LEACH) [5], CLUBS [6], Multi-hop Overlapping Clustering Algorithm (MOCA) [7], Threshold sensitive Energy Efficient Network (TEEN), Fast Local Clustering Service (FLOC) [8] and Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) [9] use particular methodologies for CH selection. The two distributed clustering algorithms that has fallen into our research interest are O-LEACH [1] and HEED [2]. In O-LEACH algorithm, the infrastructure of a sensor network is composed of a distributed optical fiber sensor (DFS) link and two separated WSN fields. The two WSN fields are crowded with randomly deployed nodes and these nodes can or cannot communicate with each other depending on the required applications.

Unlike simple WSNs, since the DFS provide data processing, at one end of the DFS link, the sink or the BS for all WSN nodes is located. The CH node compress data arriving from nodes that belong to the relevant cluster, and sends the fused data to the BS in order to further reduce the amount of information to be transmitted to the BS. After a given interval of time, to maximize the uniformity of energy consumption of the network, randomized rotation of the role of CH is conducted. Sensors elect themselves to be local CHs at any time with a certain probability. The O-LEACH algorithm is only a fairly incremental modification to the original LEACH algorithm.

Though O-LEACH protocol is comparatively much more energy efficient, the focal drawback in this approach is the random selection of CHs. In the worst case, the CH nodes may not be evenly distributed among the nodes and it will have its effect on the data gathering. Hybrid Energy Efficient Distributed Clustering (HEED) [2] is a distributed clustering algorithm which selects the CH based on both residual energy and communication cost. Principally HEED was proposed to avoid the random selection of CHs

3. THE PROPOSED ALGORITHM

The proposed algorithm, hybrid energy efficient clustering algorithm (HEECA) (figure 3) is a well distributed clustering algorithm where the sensor nodes are deployed randomly to sense the target environment. The two WSN fields are coupled with the help of distributed relay nodes.

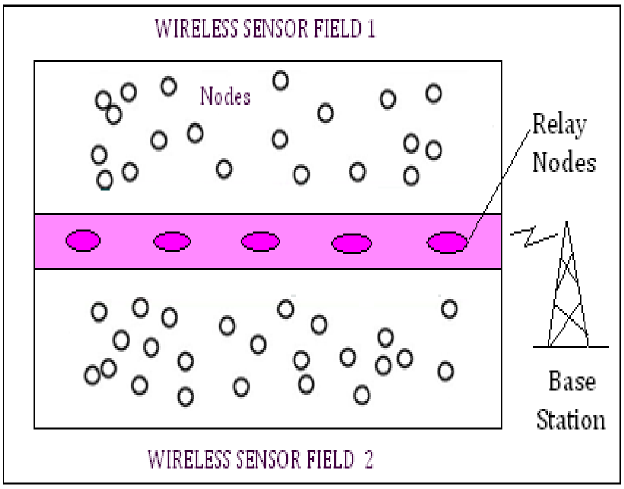

Figure 3: An articulation of HEECA algorithm

The sensor network is partitioned into clusters with each cluster having an individual CH. The nodes send the information during their TDMA timeslot to their respective CH which fuses the data to avoid redundant information by the process of data aggregation. The aggregated data is forwarded to the distributed relay nodes which in turn routes the data to BS either directly or forwarding through other distributed relay nodes. The proposed algorithm (HEECA) has four main peculiar features. First, CHs does not forward the data to BS, instead CH forwards data packets to distributed relay nodes and these richer-resourced distributed relay nodes routes data to BS thereby considerable energy utilization can be lessened.

Second, HEECA uses adaptive transmission power. Nodes closer to CH use lesser transmission power and nodes far away from CH use maximum power for transmission from nodes to CH or vice versa, which trims down considerable power [10-16].

Third, a hybrid clustering mechanism taking on the concept of threshold to avoid redundant information transmittal by the CH. Fourth, HEECA puts to use distributed relay nodes to connect two WSN fields.

Since the CHs or the regular sensor nodes automatically decides the transmission power based on its communication distance to that of the node to be communicated, it is referred as adaptive transmission power. The nodes in the cluster are divided into regions based on their distance from CH and region numbers are assigned. Lowest number is assigned to the nodes in the nearest region to CH. The nodes in the farthest region are assigned with highest region number. The nodes in the last region use maximum transmission power and the nodes in the first region uses minimum transmission power. The concept of adaptive power transmission in HEECA is drafted in figure 4. Here the first region nodes utilizes power (P_1), the second region nodes utilizes power (P_2) and so on. The transmission power increases with increase in region number.

A distributed relay node (DRN) is a node which is wealthy in resources like battery, memory, etc. In general, similar to the sensor nodes, DRNs are also battery operated devices gifted for wireless communication. The DRNs may also shorten the transmission distance between a pair of distantly located nodes by acting as a hop between them. But the type of DRNs proposed in different publications is not one-off. It has been suggested that DRNs should be of prominent capabilities than the sensor nodes in terms of initial energy provisioning, the transmission range and the data processing (data gathering and data aggregation) capability. Here, the DRNs perform two core functions: first, it routes the aggregated data from CH to the BS either directly or forwarding through other DRNs and second, it is used to provide wireless connection between two WSN fields. In the proposed algorithm, the DRNs are distributed evenly within the coverage range of the two WSN fields. The main rewards of using DRNs: extends the lifetime of sensor networks, energy-efficient cum balanced data gathering, providing fault tolerance in sensor networks and providing wireless connectivity between two WSN fields [17-21].

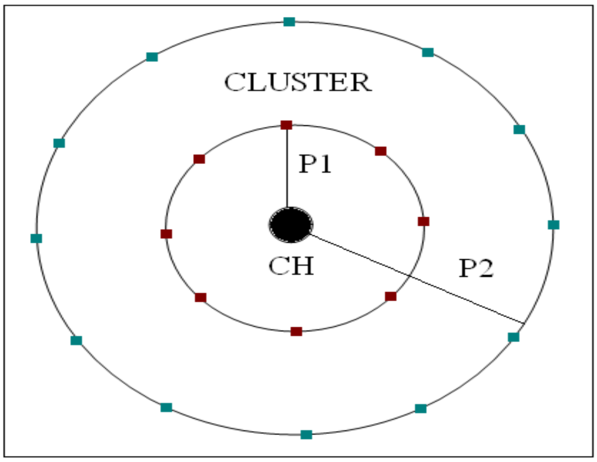

Figure 4: Adaptive transmission power in HEECA

The sensor network with 'N' nodes gets parted into 'n' individual clusters. Initially, a node with highest residual energy (RE) and good coverage with all the cluster nodes is elected as CH. The remaining nodes join to that particular CH as member nodes. The CH periodically checks the RE and coverage of the member nodes with its own and if it finds any node to have it higher, the CH role is transferred to that particular node with higher capabilities. HEECA is assumed to be formed with 'N' nodes, such that 'n' clusters are formed (equations 1 and 2) [22-26]

$$N = \left(N_1 + N_2 + N_3 + \ \ldots\ldots \ + Nn\right) \qquad (1)$$

$$Nn = \left(IN_1 + IN_2 + IN_3 + \ \ldots\ldots \ + IN_n\right) \qquad (2)$$

where 'Nn' is the number of nodes in the nth cluster and 'IN' is an individual node of a particular cluster. The concept of threshold is applied in HEECA algorithm, which is highly significant in a variety of WSN applications such as fire alert, environmental monitoring, etc. The nodes send sensor readings only when they fall above the hard threshold and change by given amount (soft threshold). As a consequence, soft threshold will further reduce the number of transmissions if there is little or no change in the value of sensed attribute. One can tweak both hard and soft threshold values in order to control the number of packet transmissions. The aggregated data is transferred by the CH to the DRNs less periodically. The concept of threshold is employed here to avoid unnecessary transmissions between CH and DRNs thereby cutting down considerable energy usage. In case of O-LEACH, a node *n* chooses a random number between 0 and 1 and computes a threshold *T*(*n*) (equation 3) as follows if $n \in G$

$$T(n) = \frac{P}{1 - P \times \left(r \bmod \frac{1}{P}\right)} \qquad (3)$$

where, P is the percentage of nodes that can turn into CHs at any time, 1/P is the number of subintervals in an interval, r is the current subinterval, G is the set of nodes that have not been CHs yet in the current interval. Comparing the random number with this threshold, a node can be either a CH or a follower in any one of 1/P subintervals of an interval. If the random number is less than the threshold T(n), the node decides to become a CH. Otherwise, it chooses to become a follower. At the first subinterval of an interval, each node has a probability P to become a CH. The nodes that were CHs in the first subinterval cannot be CHs in the next (1/P – 1) subintervals of the same interval.

The proposed HEECA algorithm sets the threshold value at the CH level in order to avoid redundant data transmission to the DRNs. The threshold value K_{thres} is assessed by the expression adopted in equation 4

$$K_{thres} = \frac{\sqrt{n}}{\sqrt{2\pi}} \sqrt{\frac{E_{CAE}}{E_{BAE}}} \frac{M}{D_{BS}^{2}} \quad (4)$$

where, N is the number of nodes in the sensor network, M is the dimension of the sensing area, D_{BS} is the distance between the CH and the base station, E_{CAE} and E_{BAE} are the amplifier energies of CH and base station respectively. In order to find out the optimum threshold value equation 5 is employed.

$$K_{thres(opt)} = \frac{\sqrt{n}}{\sqrt{\pi}} \sqrt{\frac{E_{CAE}}{E_{BAE}}} \frac{M}{D_{BS}^{2}} \quad (5)$$

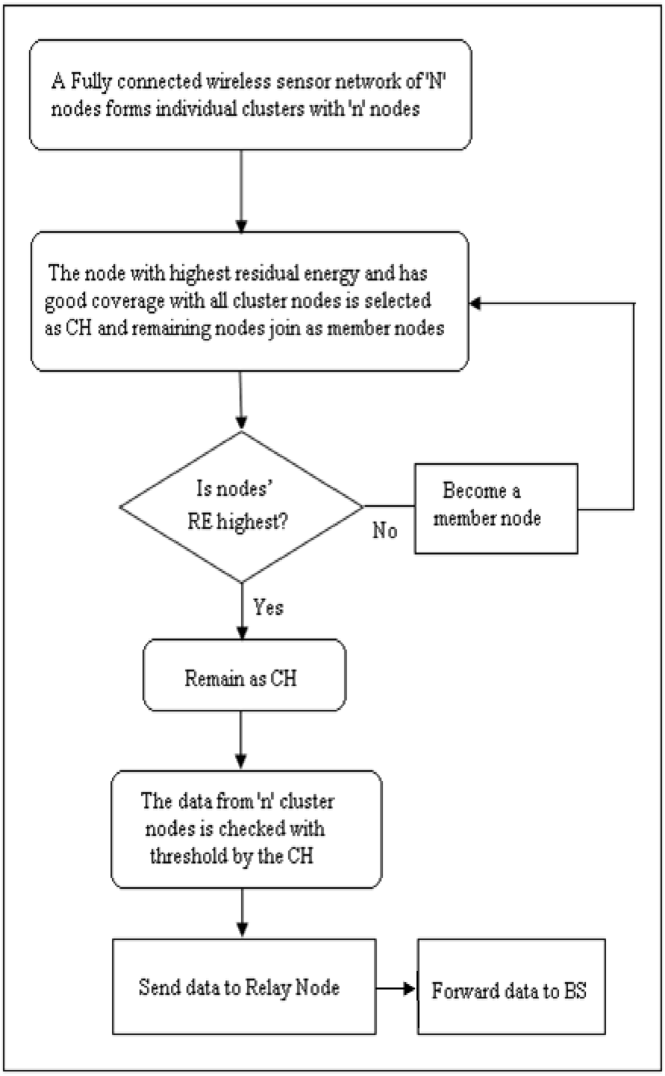

Figure 5: Hybrid cluster formation in HEECA

At the CH level it becomes obligatory to find out the optimum probability of election of CHs that depends upon energies including processing energy and energy required for data aggregation which could be understood from equation 6

$$P_{(opt)} = \frac{1}{2}\sqrt{\frac{E_{CAE}}{\lambda(E_{BAE}D_{BS}{}^{4} - E_{ELEC} - E_{DA})}} \qquad (6)$$

where, λ is the density of sensor nodes, E_{ELEC} is the energy requires for sensing, coding, modulation etc. and E_{DA} is the energy required for data aggregation. Equation 7 predicts the energy spent by a CH for data aggregation E_{DA}

$$E_{DA} = \sum_{i=1}^{n} E_{IN(i)} \qquad (7)$$

where, E_{IN} is the energy to be spend by the CH to process each individual nodes' data within a particular cluster. Generally E_{DA} is proportional to the number of nodes in the cluster and increases linearly as the number of nodes within a cluster increases.

For a single wireless sensor network field with N nodes and n clusters, the total energy consumption E_{TOT} (equation 8) for one complete cycle is based on the communication energy E_{Comm} of a sensor node, sensing energy E_{Sense} and processing energy E_{Proc} of a sensor node in the sensor network.

$$E_{TOT} = \sum_{j=1}^{N} (E_{Comm(j)} + E_{Sense(j)} + E_{Proc(j)}) + E_{DA} \qquad (8)$$

The proposed HEECA algorithm is efficiently used to connect two wireless sensor network fields with the usage of distributed relay nodes. Since two sensor fields are assumed, the overall energy E_{Over} (equation 9) spent by the nodes within two fields is based on the consideration of the energies used by the distributed relay nodes E_{DRNs}

$$E_{Over} = 2 \times E_{TOT} + E_{D} \qquad (9)$$

4. CONCLUSION

Based on hybrid clustering mechanism for cluster-setup, adaptive transmission power and distributed relay nodes, the algorithm HEECA has been formulated to form efficient clusters in a wireless sensor network to connect two WSN fields. The algorithm is analyzed and the performances are contrasted with the two well evaluated existing clustering algorithms O-LEACH and HEED. It is clearly seen that the proposed distributed clustering algorithm has shown much improvement in remaining energy and energy consumption over the existing algorithms. The evaluation of the proposed algorithm shows a drastic improvement in the throughput of the wireless sensor system. Nevertheless, the proposed algorithm can greatly prolong the overall network lifetime of the wireless sensor system.

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