*International Journal of Engineering Science Invention (IJESI)*
*ISSN (Online): 2319-6734, ISSN (Print): 2319-6726*
*www.ijesi.org ||Volume 9 Issue 6 Series II || June 2020 || PP 55-60*

# A Refined Energy Efficient Clustering Algorithm(REEC) for Wireless Sensor Networks

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***Abstract:****In recent years an efficient design of a Wireless Sensor Network has become a leading area of research. Wireless Sensor Networks (WSNs) consist of small nodes that respond and detect some type of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing. Many routing, power management, and data dissemination protocols have been specially designed for WSNs where energy awareness is an essential design issue. The clustering algorithm is a kind of key technique used to reduce energy consumption. It can increase the scalability and lifetime of the network. Energy-efficient clustering protocols should be designed for the characteristic of heterogeneous wireless sensor networks. In this paper we propose and evaluate a Refined Energy-Efficient Clustering algorithm (REEC) for wireless sensor networks.*

***Index Terms:*** *Wireless sensor networks; clustering algorithm; energy-efficiency, agricultural network.*

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Date of Submission: 18-06-2020 Date of Acceptance: 04-07-2020

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## I. INTRODUCTION

Wirelesssensornetwork(WSN)consistsof spatially dispersed independent devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations [1]. This network contains a large number of nodes which sense data from an impossibly remote area and send their reports to a processing center whichiscalled–basestation.Since,sensornodesare power-constrained devices, frequent and long-distance transmissions should be minimized in order to prolong the network lifetime [2], [4]. Thus, direct communications between nodes and the base station are not encouraged. One effective approach is to divide the network into several clusters and each cluster will have a cluster head [6]. The cluster head collects data from sensors in the cluster which will be fused, aggregated and transmitted to the base station. Thus, only some nodes are required to transmit data over a long distance and the rest of the nodes will need to perform only short-distance transmission. Therefore, more energy is saved and overall network lifetime can thus be prolonged. Many energy-efficient routing protocols are designed based on the clustering structure where cluster-heads are elected periodically [12], [7]. These techniques can be extremely effective in broadcast and data transmission [11], [5].DEECheterogeneous wireless sensor networks which is based on clustering, where the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes. Thus DEEC can prolong the network lifetime, especially the stability period, by heterogeneous aware clustering algorithm. The DDEEC [3], Developed Distributed Energy- Efficient Clustering, permits to balance the cluster head selection overall network nodes following their residual energy. So, the advanced nodes are to be selected as cluster heads for the first transmission rounds, and when their energy decrease sensibly, these nodes will have the same cluster head election probability like the normal nodes. BEENISH [9] implements the same concept as in DEEC, in terms of selecting CH which is based on residual energy level of the nodes with respect to average energy ofnetwork. However, DEEC is based on two types of nodes; normal and advanced nodes. BEENISH uses the concept of four types of nodes; normal, advance, super and ultra-supernodes.

In this paper we propose and evaluate a new Refined Energy-Efficient Clustering algorithm (REEC) for wireless sensor networks. The remainder of the paper is organized as follows. In section 2, we briefly review related work. Section 3 describes the network setup used in the algorithm. In section 4, we present the details of the proposed REEC algorithm. The simulation results are given in section 5. In section 6, a real time application of our proposed algorithm is explained. Finally, conclusion and scope for future work arepresented.

## II. DEECPROTOCOL

DEEC uses the initial and residual energy level of the nodes to select the cluster-heads. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is used to compute the reference energy that each node should expend during a round. In this protocol, different $n_i$based on the residual energy $E_i(r)$ of node $s_i$ at round r. Let $p_i = 1/n_i$, which can be also regarded as average probability to be a cluster-head during $n_i$ rounds. When nodes have the same amount of energy at each epoch, choosing the average probability $p_i$ to be $p_{opt}$ can ensure that there are $p_{opt}N$ cluster-heads every round and all nodes die approximately at the same time. If nodes have different amounts of energy, $p_i$of the nodes with more energy should be larger than$p_{opt}$.Let$\bar{E}(r)$denote the average energy at round r of the network, which can be obtained by $\bar{E}(r) = 1/N\sum_{i=1}^{n} E_I(r)$To compute $\bar{E}(r)$, each node should have the knowledge of thetotal energy of all nodes in the network. They calculate the optimal cluster-head number that they want to achieve. They get the probability threshold, that each node $s_i$ use to determine whether itself to become a cluster-head in each round, as follow:

$$T(s_i)= \begin{cases} \frac{p_i}{1-p_i\left(r mod \frac{1}{p_i}\right)} \; if \; s_i \in G \\ 0, otherwise \end{cases}$$

Where, G is the set of nodes that are eligible to be cluster heads at round r. If node $s_i$ has not been a cluster-head during the most recent $n_i$ rounds, then there is a possibility for it to become a cluster head. In each round r, when node$s_i$ finds it is eligible to be a cluster-head, it will choose a random number between 0 and 1. If the number is less than threshold $T(s_i)$, the node $s_i$ becomes a cluster-head during the current round. The epoch $n_i$ is the inverse of $p_i$. $n_i$ is chosen based on the residual energy $E_i(r)$ at round r of node $s_i$ The rotating epoch $n_i$ of each node fluctuates around the reference epoch. The nodes with high residual energy take more turns to be the cluster-heads than lowerones.

They evaluated the performance of DEEC protocol using MATLAB. For they considered a wireless sensor network with N = 100 nodes randomly distributed in a 100m X 100m field and assumed the base station is in the center of the sensing region. To compare the performance ofDEEC with other protocols, they ignore the effect caused by signal collision and interference in the wirelesschannel.

## III. NETWORKSETUP

In our proposed algorithm we consider the network setup used in DEEC, which consists of N nodes, which are uniformly dispersed within a M X M square region. The network is organized into a clustering hierarchy, and the cluster-heads collect measurements information from cluster nodes and transmit the aggregated data to the base station directly. Moreover, we suppose that the network topology is fixed and no-varying on time. We assume that the base station is located at the center.

The energy expended by the radio to transmit an L-bit message over a distance d is given by:
$E_{tx}(L; d) = LE_{elec} + LE_{fs}d^2$ if $d < d_0 LE_{elec} + LE_{mp}d^4$ if $d \geq d_0$, where $E_{elec}$ is the energy dissipated per bit to run the transmitter ($E_{TX}$) or the receiver circuit ($E_{RX}$). The $E_{elec}$ depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. $E_{fs}$ and $E_{mp}$ depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. For the experiments described here, both the free space ($d^2$ power loss) and the multi path fading ($d^4$ power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used. In DEEC they have fixed the value of $d_0$ randomly as $d_0 = 70$. But in our proposed algorithm we are calculating the value of $d_0$ using the concept of Euclidean distance between the nodes.

Given a network of n nodes we are interested in identifying the clusters of nodes along with their cluster heads. Our algorithm starts with random generation of n nodes in a fixed square region. Basically it is assumed that each and every node can communicate to the base station and to all other nodes in the network. The square region selectedis subdivided into squares of equal side and the distances between the center of each sub square and all other nodes in that sub square are calculated. The node, whose distance is minimum is selected as the cluster head of the nodes belonging to that sub square. The cluster heads are connected to the base station and hence all the n nodes of the network will have a unique path for communication with the base station through their corresponding cluster head. For comparison purpose, REEC is implemented using the same parameters used in DEEC.

## IV. REECALGORITHM

In this section, the proposed REEC algorithm is presented which consists of two modules. In the first module, the nodes are randomly generated in a fixed square region. Cluster formation and initial routing in the network are achieved by considering the nodes as homogeneous and the cluster heads are elected using Euclidean distance between the nodes. In the second module, node which is to communicate with the base station is received as an input and the path through which the communication takes placeis identified from the second round onwards the nodes are considered as heterogeneous and the cluster-heads are elected based on the residual energy of each node. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the nodes with low energy. If there is more than one node with same energy, the one which is closer to the centroid of the region will be elected as cluster heads. The cluster heads to the subsequent rounds are selected according to the residual energies of thenodes.

**Proposed Algorithm:**

**Module I: Formation of network and First round communication**

- Create a square area of N X Nmeters
- Randomly generate a network of m nodes and identify the Cartesian location say ($x_i$, $y_i$) for i =1, 2, …,m
- Locate the base station (BS) at (N/2,N/2).
- Divide the square region into n sub squares each of side N/sqrt(n)
- For each sub square, find thecentroid.
- In each square, for the nodes inside and on the boundary of the square calculate the Euclidean distances between the nodes and corresponding centroid. Identify the node with minimum distance as cluster head in that square region.
- In each square, connect the corresponding cluster head to the remaining nodes in thatsquare
- Connect all cluster heads toBS
- For all cluster heads $C_k$ = ($x_k$, $y_k$), calculate the distances $d_k$ from the cluster heads to BS and find the average of all these distances. Let it be $d_{toBS}$
- In each square, calculate the distances between the cluster head $C_k$ within that square and remaining nodes in that square. Find the average of these distances let it be d to $k^{th}$ cluster. Let the average of all these distances be $d_{toCH}$
- Calculate the energy dissipated from the node $N_i$ for one transmission of L bits using $L*(2\ E_{elec}+\ E_{mp}*\ d_{toCH}^4)$.
- Display the energy of node $N_i$ after everytransaction.
- $E_{elec}$ is the energy dissipatedper bit to run the transmitter ($E_{TX}$) or the receiver circuit ($E_{RX}$). The $E_{elec}$ depends onmany factors such as the digital coding, the modulation, the filtering, and the spreading of the signal.
- Calculatetheenergydissipatedfromtheclusterheadforone transmission of L bits using $L*(2\ E_{elec}+\ E_{fs}*\ d_{toBS}^2+E_{DA})$

**Module II: Consecutive rounds**

- In each square the node with maximum energy is selected as the cluster head for the nodes in that square. If there is more than one node with same (maximum) energy the one nearest to the centroid of that square becomes new cluster head for the correspondinground.
- Transaction takes place with the newrouting.
- Energy of each node is displayed after everyround.
- The number of rounds from the particular node until it becomes dead (ie. its energy reduced to the level with which further transaction cannot be done from that node) is calculated.

**Parameters to be used for simulation**

| Parameters | Value |
|---|---|
| $E_{elec}$ | 5nJ/bit |
| $E_{fs}$ | 10pJ/bit/m$^2$ |
| $E_{mp}$ | 0.0013 pJ/bit/m$^4$ |
| $E_0$ initial energy for nodes | 0.5J |
| $E_{DA}$ | 5 nJ/bit/message |
| Message size | 4000 bits |

## V. SIMULATIONRESULTS

The above algorithm is implemented in NetSim by interfacing with MATLAB and tested for different userinput values for the number of nodes. Figure 1 is a 1000m X 1000m square region in which 50 nodes where deployed. Figure 2 is the clustered network of 50 nodes whose cluster heads are connected to the base station, in which any node can communicate to the base station through its cluster head. Figure 3, depicts that there is a transaction takes place between node 1 and the base station through the clusterhead

Module II is also coded using the parameters mentioned above and Figure 4 shows that the next transaction from the same node takes place through the new cluster head 4 which is highest energy node in that cluster after the first transaction. Accordingly, the energies of the nodes will be reduced using the calculations explained in the algorithm and considered for further routing.

**Sample Outputs:**

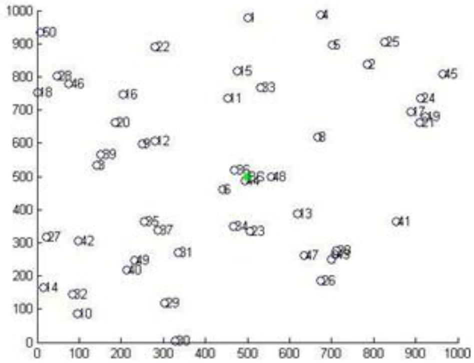


**Figure 1.** Node Generated

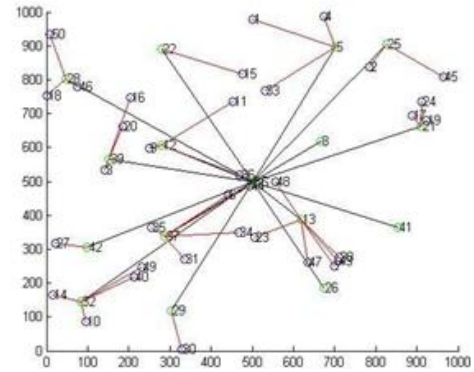


**Figure 2.** Network Generated

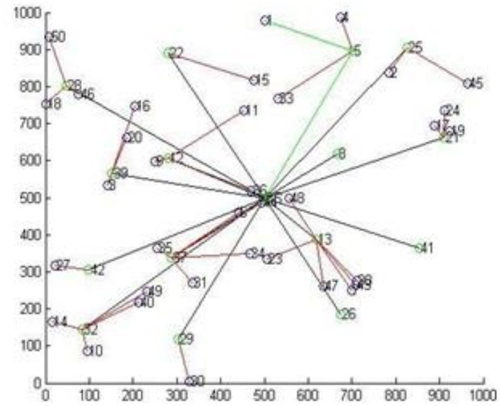

**Figure 3.** First routing

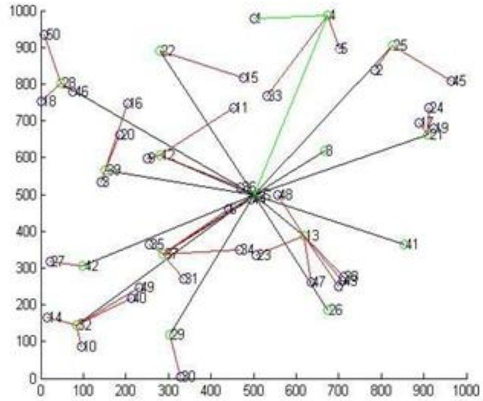


**Figure 4.** Second routing

The simulation results show that REEC achieves longer lifetime and more effective message transmission. By repeatedly using the same node 1 for transactions we are able to identify that the Node 1 is live for more 100 transactions of uniform message length of 10000 bits. In this regard life time of the network is improved and hence our proposed algorithm REEC is claimed to beefficient.

## VI. APPLICATION OF REECINAGRICULTURAL NETWORK

In recent years, WSNs are widely applied in various agricultural applications. A field is instrumented with sensor nodes which are equipped with sensors for measuring important parameters like air temperature, relative humidity, light intensity, rainfall level, air pressure, and moisture. The main intention is to forecast the crop health and production quality over time. Irrigation scheduling is predicted with WSNs by monitoring the soil moisture and weather conditions. The issues present in such applications are the determination of optimal deployment strategy, measurement of interval, energy-efficient medium access, and routing protocols[10].

Suppose, we assume that the agricultural fields are of square regions (Figure 5). Then we divide them into sub squares of equal sides and the sensor nodes are placed randomly on to the field. Hence our Refined Energy Efficient Clustering (REEC) algorithm could be applied to identify the cluster heads and routing path for communication. Since in REEC energy is taken into account while finding the routing path for the second and forth coming communications, this method will result in an energy efficient clustering for agricultural network. Under this routing topology, the base station gets the data about the parameters, from the sensor nodes through the cluster heads and will be analyzedfurther.

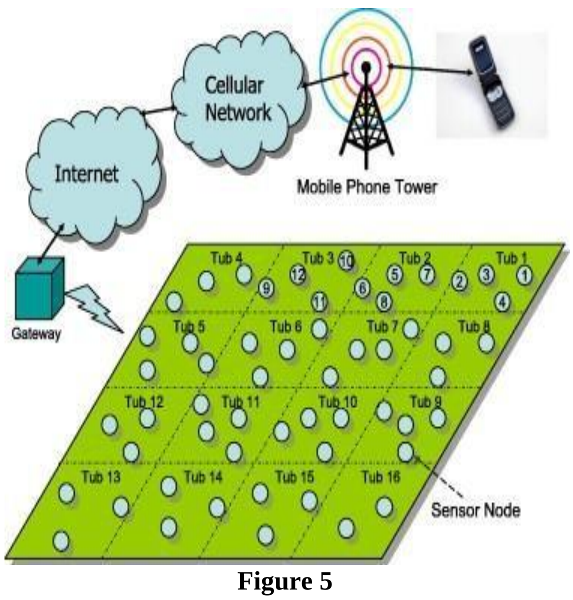


**Figure 5**

## VII. CONCLUSION

In this paper we proposed a refined energy efficient clustering algorithm for heterogeneous wireless sensor networks. In our proposed system, initially for the first round, the nodes are considered as homogeneous one and the clustering and identification of cluster head are achieved using the Euclidean distance between the nodes. Cluster heads are connected to the base station to get a complete routing in the network. After a transaction, new clustering and cluster heads are selected based on the residual energies of the nodes. Proposed REEC algorithm is simulated using NetSim interfacedwith MATLAB. Further, the comparisonof our algorithm with other existing algorithms could be done and the efficiency of the algorithm is to be justified.

## ACKNOWLEDGEMENT

The authors would like to acknowledge Mr. T. S. Lagnesh, BE Mechanical Engineering, PSG College of Technology, Coimbatore for his support in developing the coding for proposedwork.

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SangavaiKrishnamoorthi and Porkodi Chinniah, "A Refined Energy Efficient Clustering Algorithm (REEC) for Wireless Sensor Networks."*International Journal of Engineering Science Invention (IJESI)*, Vol. 09(06), 2020, PP 55-60. Journal DOI- 10.35629/6734