Enhanced Unequal Clustering Scheme for Wireless Sensor Networks

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ABSTRACT
In wireless sensor networks, the lifetime of a sensor network is a hottest research topic. Clustering provides an efficient method for increasing the network lifetime. Existing clustering algorithms selects the cluster head with high residual energy and rotates the cluster head periodically to distribute the energy among the nodes in each cluster. Cluster head has the responsibility for collecting data from its cluster members and then it forwards them to the base station. As a result, each node spends more energy for re-electing the cluster head frequently and gathering data from its cluster members. The hot spot problem and distributing the energy consumption among the nodes are the major issues in clustering. To mitigate the hot spot issue and preserve energy for multihop data forwarding, an enhanced clustering scheme namely EUCS is proposed. It constructs the clusters of unequal size and clusters closer to the base station have smaller in size. The cluster head can be re-elected when the energy level of current cluster head reaches to its predefined threshold value which reduces the frequent re-election of cluster head. In addition, to preserve some more energy, data from the sensor nodes are directly transferred to the nearest cluster heads which forwards them to the base station to avoid data gathering in the cluster head. The simulation results show that our algorithm increases the network lifetime effectively.

General Terms
Wireless Sensor Networks, Clustering.

Keywords
Hot spot problem, Network Lifetime.

1. INTRODUCTION
Wireless sensor networks consists of a large number of small size sensor nodes which form an ad-hoc distributed network and able to communicate unlethered within a short distance. The sensor nodes have stringent power limitation and replenishment of power is impossible in some application scenario. Due to the strict energy constraint, the energy resource of sensor networks should be managed wisely to extend the lifetime of sensor. In order to attain high energy efficiently and increase the network scalability, sensor nodes can be structured into clusters. Clustering can obviously reduce energy consumption.

The network lifetime of a sensor and the lifetime of a network which directly determines the duration of sensing task, is limited by the amount of energy each sensor has.
Therefore, when we examine these networks, the efficient use of energy is a primary concern. The main issue of our interest is to maximize the lifetime of a sensor network for a given amount of energy.

In this paper, the proposed algorithm mitigating the hot spot problem and increasing the lifetime of the network. It is a distributed unequal clustering algorithm, where cluster heads are selected with high residual energy of each sensor nodes and distance from the base station. It partitions the nodes into unequal sized clusters, and clusters closer to the base station are smaller in size than those farther away from the base station. To preserve more energy for each sensor, the cluster heads are not elected periodically. It can be re-elected based on some constraints to avoid frequent re-election of cluster head. The proposed algorithm successfully balances the energy consumption over the network and achieves a remarkable network lifetime improvement.

2. RELATED WORK
This section briefly discusses some well-known unequal clustering algorithm in WSN. Energy Efficient Unequal Clustering (EEUC) is a competitive based distributed unequal clustering algorithm is proposed where cluster-heads are elected based on the high residual energy of its neighbor and its distance to the Base Station [6]. To address the hot spot problem, EEUC separates the nodes into a cluster of unequal size, and cluster nearer to the base station has smaller sizes that those farther away from the BS because the node could not communicate directly to the BS due to the limited transmission range. It cannot guarantee that each node belongs to a cluster, and it is probable that a number of nodes cannot join any one cluster due to cluster head election mechanism based on probability. Soro and Heinzelman, *at el*. [7] proposed an unequal clustering size (UCS) to balance the energy consumption of cluster heads due to heavy inter-cluster relay traffic. The CH positions are determined in before, and CHs are arranged in symmetrically concentric circle around the base station. It assumes that all clusters has the same size and shape but it differst from one another. In multi-hop networks, it was 10-30 % better than existing equal clustering models. An unequal cluster-based routing protocol (UCR) is designed for inter-cluster relay traffic, which considers the transaction between the energy cost of relay links and the residual energy of relay nodes [8]. UCR does not require any special location awareness capability. In real environment, error will arise due to the noise. An energy-

driven unequal clustering protocol [EDUC] use uneven competition ranges to construct clusters of uneven sizes [10]. Each node acts as cluster head no more than once during the whole network lifetime. Thus, EDUC minimizes the extra cost and achieves high energy efficiency.

Multihop Routing Protocol with Unequal Clustering [MRPUC] elects the CH in rounds with high residual energy [11]. To mitigate the hot spot problem, the MRPU adopts the multihop transmission and construct an inter-cluster tree rooted at Base Station to save energy. The interval between the dead time of the first node and dead time of the last node is determined to increase the performance of the protocol,.

In [12] is an unequal clustering algorithm, based on HEED algorithm. It creates unequal sized clusters based on the distance of the CH from the BS. The data captured in a cluster is highly correlated; therefore it can be aggregated before being transmitted to the base station. UHEED efficiently mitigates the hot spot crisis of unequal sized clusters and thus balances the energy levels of CHs in the network. An Energy-Efficient Distributed Unequal Clustering [EEDUC] is a distributed unequal clustering algorithm, in which each sensor nodes uses a waiting time to distribute the CH [13]. The waiting time is considered as a function of residual energy of each node, number of neighborhood node. In EEDUC, the performance of energy consumption is improved by 24.2% compared to EEUC.

All the above proposed algorithms spend more energy while rotating the cluster head periodically and gathering data from its cluster members. Some algorithms provide solution for mitigating the hotspot problem and some algorithm concentrated on increasing the efficiency of network life time, but both are not addressed together. This paper mitigates the hot spot problem by forming an unequal cluster and increasing the network lifetime by reducing the number of re-clustering and data gathering in cluster head.

3. PROPOSED WORK

A. Network Model

Let us consider a set of sensor nodes that are uniformly distributed in a square field area. Base Station (BS) is located at the centre of the network area. After Deployment the nodes and the BS are all stationary. Sensors are homogeneous and each node is assigned by an unique ID. If the transmission power is given, the approximate distance can be calculated from one node to another node based on the received signal strength. The radio energy dissipation model [4] is used to transmit k bit message over a distance d is:

$$ET_x\ (k,d) = \begin{cases} k * E_{elec} + k * €_{fs} * d^2, & d < d0 \\ k * E_{elec} + k * €_{mp} * d^4 & d \geq d0 \end{cases} \quad (1)$$

Where Eelec denotes the electronic energy and the ratio of €fs and €mp is constant, that denotes the amplifier energy to maintain the acceptable signal to noise ratio. The energy spent to receive the message is calculated as follows.

$$ER_x(k) = k * E_{elec} \quad (2)$$

After the deployment of sensor nodes, the base station broadcasts ADV-Msg to all nodes within the radio signal r, to calculate the distance from the Base Station to node itself according to the received signal strength. To produce an unequal cluster, each node to compute its own competition radius. The radius of the cluster is defined as following:

$$R_c = 1 - c\,\frac{d_{max} - d_{(si,BS)}}{d_{max} - d_{min}}\,R_c^0 \quad (3)$$

Where d_{max} and d_{min} denotes maximum and minimum distance between sensor nodes and base station, $d(s_i, BS)$ is the distance between s_i and the base station, c is a constant, R^0_c is the maximum competition radius which is predefined. Each node broadcasts HELLO-Msg to its neighbor within the range of d_{max} and collects the information such as node ID, residual energy and number of distance of the neighbor.

After receiving the HELLO-Msg from the neighbor, the average residual energy of the sensor node using is calculated the following equation:

$$E_a = \frac{1}{d} \sum_{i=1}^{d} s_i\ E_r \quad (4)$$

Where *si* denotes one of the neighbor nodes, s_i· E_r denotes the residual energy of s_i, and *d* is the number of neighbor nodes. If a node s_i has the highest residual energy among all neighbor nodes, it is elected as the cluster head and broadcasts a HEAD-Msg to its neighbor within the range of d_{max}. Each node chooses the nearest cluster head and sends the JOIN-Msg which contains the node id and its residual energy.

After the cluster head is initialized, set minimum residual energy as a threshold value RE_{min}. Broadcasts THRE-Msg to all the cluster heads for re-electing the cluster head. When the cluster head reaches the threshold value, then the cluster head can be re-elected. The pseudo code of re-election of CH is described in Algorithm 1:

Algorithm 1: Re-election of Cluster Head

RE_{min}=minimum residual energy
Broadcast THRE-Msg(ID,E_{min}) message to all the cluster heads
RE=current cluster head residual energy
While (RE > RE_{min}) do
    Call the cluster setup procedure
    Reselect the cluster head
End while
End

Once the cluster formation is finished, data transmission begins. In some proposed algorithms [6-13], the cluster heads aggregate the data from its cluster members and sends the data to the base station in multihop communication. In this paper, the incoming data is forwarded to the nearest cluster head instead of forwarding to the cluster members to avoid data gathering. Each cluster head chooses the next cluster head by forwarding its data from its nearest neighborhood cluster heads. The pseudo code for choosing the nearest cluster head for data forwarding is described in Algorithm 2:

Algorithm 2: Choosing nearest CH for data Transmission

DTHR=min
S_i=CH
d=distance from s_i to BS
if (d<DTHR) then
  s_i directly communicate with BS
else
  repeat
    s_i selects s_j from its neighbor
    if(s_j=CH of neighbor cluster)
      Forward the data from s_i to s_j

endif
While (s_j=CH)
Endif

If the distance from the CH to the Base Station is less than the assigned threshold value, then the CH directly communicates with the Base Station, otherwise choose the relay node s_j for forwarding the data to Base Station. If s_j is a CH then forward the data otherwise repeat the steps to select the CH as a relay node with high residual energy among the neighborhood CH.

Each cluster head consumes some energy for selecting a relay node to forward the data to the base station. The formula for calculating the energy consumption for choosing the next hop as cluster head is.

$$E_{relay} = d^2(s_i, s_j) + d^2(s_i, BS) \qquad (5)$$

Where d (s_i,BS) is the distance from the current cluster head s_i to the base station. s_j is the next hop for s_i. d (s_i,s_j) is the distance from current cluster head to the next cluster head s_j. The control messages and its descriptions shown in table 1:

Table 1: control messages and its descriptions

Control messages	*Descriptions (fields)*
Hello_Msg	*Node ID, Residual Energy E*
Head-Msg	*Node ID*
Join_Msg	*Node ID, Head ID*
Sync_Msg	*Node ID, Residual Energy E*
THRE_Msg	*Node ID, Residual Energy*

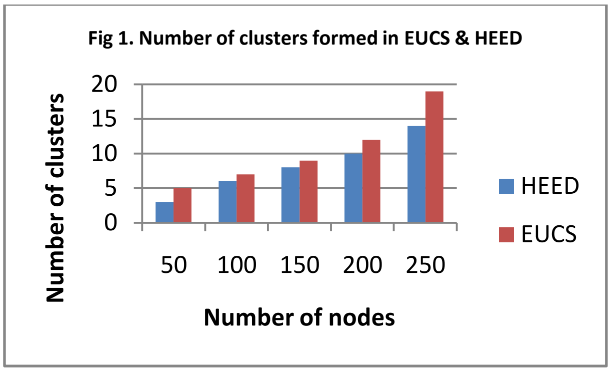
5. SIMULATION AND RESULTS

The simulation has been done in Network Simulator tool. Let us assume a homogeneous wireless sensor network with 50-250 nodes that are distributed randomly in a square field. The base station is positioned at the center. The values for the horizontal and vertical coordinates of each sensor are assigned from o to the maximum value. We evaluated the performance of our algorithm with HEED and three metrics are chosen for comparison: Residual Energy of each node, Cluster Head re-election and Network lifetime. The simulation parameters are described in table 2:

Table 2: Simulation Parameters

Parameters	Values
N	250
BS Location	200,100
Packet size	500 bytes
Network distribution	Square fields
Sensor field	200 m * 200 m
Initial energy of node	2J

Figure1. Shows that proposed algorithm avoids the hot spot issue by increasing the number of clusters nearer to the base station when increasing the number of nodes in sensor fields.



The residual energy is maintained for a long time in EUCS compared to HEED in figure 2.

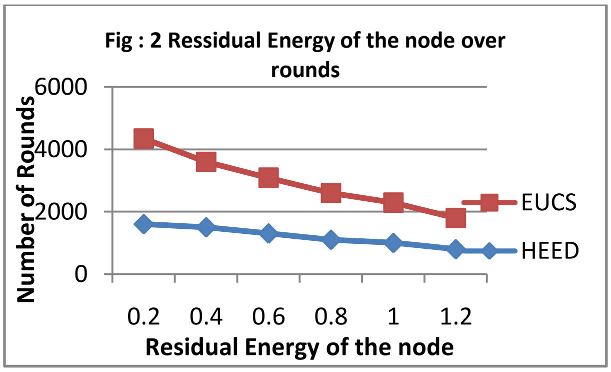


Figure 3 clearly shows that the nodes nearer to the base station die much faster than the nodes farther away from the base station. Compared to HEED, our proposed algorithm increases the network lifetime of each node nearer to the base station by increasing the number of nodes closer to the base station and it will prevent the node from dying earlier.

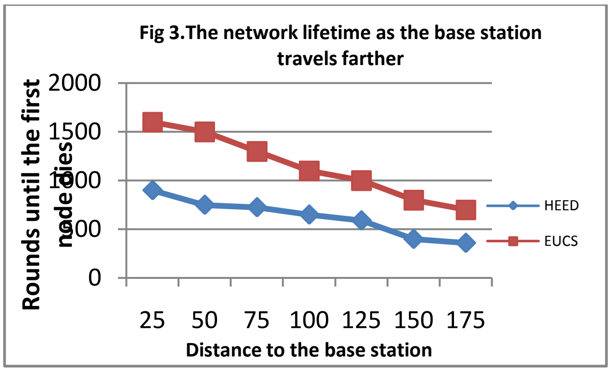


Fig 3.The network lifetime as the base station travels farther

Figure 4 shows, the number of CH re-elected with respect to the number of nodes. The initial energy of each node is assigned as 1.2 joule. The minimum energy is 0.2. The cluster head re-election is reduced when compared to HEED.

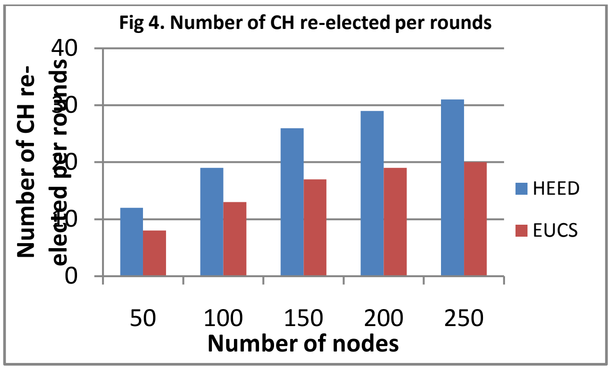


Fig 4. Number of CH re-elected per rounds

Figure 5 shows the number of live nodes for HEED and EUCS after 1500 rounds. 65% of the nodes have lost their energy and almost 160 sensor nodes are in live position. But in the case of EUCS, the simulation result of live nodes after 1500 rounds are 210 nodes out of 250 nodes. The network life time of the sensor network is proportionally increased and the energy consumed well. The total energy efficiency is increased nearly by 42% than the HEED algorithm. The sensor nodes are under dead position after 3500 rounds. This is clearly giving a good result of the proposed algorithm.

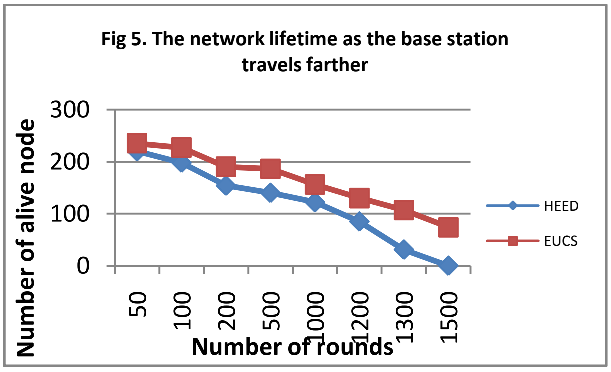


Fig 5. The network lifetime as the base station travels farther

The sensor nodes in EUCS consume less energy than the nodes in HEED. In scenarios with more nodes, the sensor nodes in HEED have to consume more energy to communicate with the Base station because of the longer distance between sensor nodes and the base station. However, in EUCS, the number of clusters nearer to the base station is more than HEED. This will consume less energy for a single node as shown in figure 6.

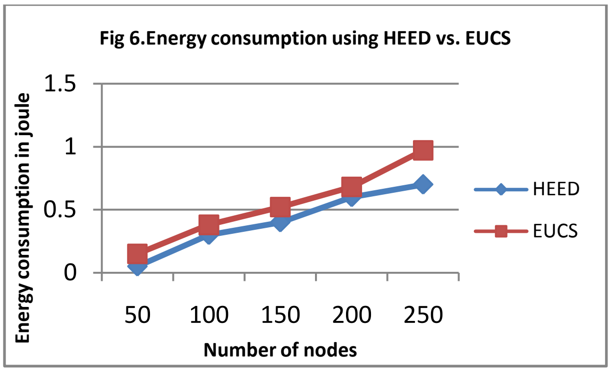


Fig 6.Energy consumption using HEED vs. EUCS

6. CONCLUSION AND FUTURE WORK

In this paper, the proposed algorithm which selects the cluster head based on highest residual energy of neighbor nodes. An unequal cluster is constructed to avoid the hot spot issue. In addition, we also propose, to preserve more energy, i) avoid data gathering from its cluster members by choosing nearest cluster head for data forwarding to base station, ii) reduces the frequent re-election of cluster head by setting a predefined threshold value for each cluster head. The results show that the proposed algorithm has confirmed that it provides a longer network lifetime as compared to HEED. In future, the EUCS will be implemented in heterogeneous networks to increase the network lifetime and consume energy more efficiently. It will also include the fault tolerant mechanism in heterogeneous networks.

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