NHEEP: A New Hybrid Energy Efficient Partitioning Approach for Wireless Sensor Network Clustering

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Abstract—**Wireless Sensor Networks (WSNs) consist of hundreds of micro sensor nodes which are restricted from the energy supply, computational capacity, and storage resource point of views and are randomly deployed in harsh environments. In order to increase load balancing and lifetime of the WSNs, different clustering algorithms are used. In this paper, a new clustering approach presented based on a partitioning technique in which the number of partitions are determined with a ratio of optimal number of cluster heads (CHs) to the total number of nodes. There are some parameters are used in selecting CH in each partition including: position and distance of the nodes, and a special parameter that has a direct relation with energy limitation which is called EL. Simulations results show that proposed method can increase performance and energy efficiency comparing with LEACH and HEED. Also, network lifetime will be enhanced by decreasing energy consumption and transmission overhead.**

Index Terms—**Wireless sensor networks, clustering, leach, partitioning.**

I. INTRODUCTION

Recent advancements in integrated circuits and wireless communication have been offered a new technology that has enabled to sense phenomenon in unavailable region. This technology has called Wireless Sensor Network which consists of tiny, inexpensive, low- power sensors [1].

Sensor nodes are relevance with each other via wireless communications and enable us to use them in specific environments to research or monitoring. These networks are becoming more and more useful in both military and civil applications such as real-time traffic monitoring, critical infrastructure, emergency response, surveillance, pollution monitoring, building safety monitoring, and battlefield operations [2].

Such networks consist of hundreds of sensor nodes deployed via individual installation or random scattering. Each node is equipped with a special sensor to capture information continually in certain area and report it to the base station which is called sink. Since nodes use batteries as their energy power and it is impracticable to change them so they are usually highly power constrained. Therefore, energy limitation is a critical problem [1].

A proper solution to solve limited energy is clustering. Clustering is a fundamental mechanism to design scalable sensor network protocols [2].

A clustering algorithm splits the network into separate sets of clusters that each one has a CH. An important issue in clustering is selecting appropriate CHs which do data aggregation and manage nodes in their clusters. A suitable clustering compels a regular, high level structure on the network [3]. So, CHs are similar to other nodes as hardware and software structure. There are many aspects to elect CH such as nodes distance to destination, nodes residual energy, number of neighbor nodes and so on.

The main idea of NHEEP algorithm is using dynamic partitioning and EL parameter to reduce energy consumption to select CH to do this, using nodes with high energy is useful too.

The rest of this paper is organized as follow related works was presented in section 2, Network model are described in section 3 and in section 4 we propose clustering algorithm to enhance efficiency of network. Simulation result and Performance evaluation peruses in section 5. Finally section 6 concludes the paper and discusses our future research plan.

II. RELATED WORKS

Heinzelman et.al presented a hierarchical clustering algorithm for wireless sensor networks which is called Low Energy Adaptive Cluster Hierarchy (LEACH). In LEACH, selected node as CH will be changed during each rounds. That have been CH cannot be CH again in next P rounds. Therefore, each node has a 1/p probability of being a CH in each round. At the expense of each round, each node that is not CH selects the closeness CH and joins to it and sends its data to CH. Then it aggregate and forward them to the sink, The CHs use Time Division Multiple Access (TDMA) as a scheduling mechanism which makes it long delays when applied to large sensor networks. In this algorithm, energy consumption will distribute almost between all nodes uniformly and the non-head nodes are turning off as much as conceivable. LEACH supposes that all nodes are in range of sink which is not the case in many sensor extensions. In each round, LEACH has CHs comprisal 10% of total nodes [4]. Suchlike randomized rotation may not be appropriate for inquiry processing as the set of CHs for a time period cannot be determined a priori or externally [5].

Ossama Younis and Sonia Fahmy are presented a new clustering algorithm which is called HEED (Hybrid Energy-Efficient Distributed clustering) that elects CHs according to hybrid quality alternatively, primary of the node residual energy and secondary parameter, such as node closeness to its neighbors or node's degree. HEED concludes in O(1) iterations, obtains low message overhead, and achieves steady CH distribution across the network clearly [6].

In LEACH-centralized (LEACH-C) algorithm which is presented in 2002 has two phases, set-up and Steady-State.

During set-up phase, each node sends information about its current position and energy level to sink. In addition to determining proper clusters, sink needs to ensure that the energy load is fairly distributed among all nodes. Thus, it computes the average node energy and each nodes that the average of it's energy is low, cannot be CH in the current round. From the remaining nodes as possible CH, sink chooses CHs by using the simulated annealing algorithm [7]. Actually, it is the NP-hard problem and greedy to find k optimal clusters. The simulated annealing tries to minimize significant amount of energy that non-CH nodes need to transmit their data to the CH, by minimizing the total amount of distance between all the non-CH nodes and their CHs [8].

Abrams et al. proposed a distributed algorithm for set k-cover is proposed. The set of sensors are partitioned into *covers* and the covers are activated iteratively in a round-robin fashion so that energy efficient monitoring of the sensor network can be achieved. The set k-cover algorithm can be applied to the time-indexing storage problem by mapping each partition to a time interval. However, in the set k-cover formulation, each sensor is limited to only one partition, and the activation is done in a round-robin fashion. This is, in general suboptimal in terms of network longevity [9].

PLEACH (partition-based LEACH) is like as LEACH-C that centralized CH selection scheme is deployed in PLEACH and adopts the centralized CH selection scheme. This algorithm includes two phases: at first, sink node calculates the optimal number of CHs for a given network and partitions the whole network into sectors accordingly. Second, the sink node elect a node as CH in each cluster which has most energy and then broadcast this node's id into whole network and all non CH nodes join its closest CH [10].

Another protocol to enhance efficiency of LEACH protocol was proposed by Stephanie Lindsey and Cauligi S. Raghavendra that is called Power Efficient Gathering in Sensor Information Systems (PEGASIS). The protocol is a near optimal chain-based protocol for extending the lifetime of network.

In PEGASIS, each node will receive from and transmit to a close neighbor by adjusting its power signal to be only heard by this closest neighbor. Each Nodes uses signal strength to measure the distance to neighborhood nodes in order that it may be easier to locate the closest nodes. After chain Formation PEGASIS selects a leader from the chain in terms of residual energy every round to be the one who amasses data from the neighbors to be transmitted to the sink. As a result, the average energy spent by each node in each round is reduced. Against LEACH, PEGASIS avoids cluster to form and uses only one node in a chain to transmit to sink instead of multiple nodes. This approach reduces the overhead and lowers the bandwidth requirements from sink.

III. NETWORK MODEL

Given n sensors are randomly deployed in A*A square area, that collect data during each round. We assumed, Sink is at the center of the area with the coordinate of (A/2, A/2). According to actual model, the network has the following features:

- All nodes have been uniformly distributed within a square area.
- Each node has a unique ID.
- Each node has a fixed location and knows its geographic coordinate (x, y).
- All nodes can perform data aggregation.
- All nodes are in the communication range of the sink.
- Transmission energy consumption is proportional to the distance of the nodes.

Each sensor node is equipped with sending and receiving unit and both of these activities consume energy power. Energy consumption during transmission scheme can be computed as:

$$E_{tx}(l,d) = E_{tx\text{-}elec}(l) + E_{tx\text{-}amp}(l) = \begin{cases} lE_{elec} + l\varepsilon_{fs}\, d^2 & ,d < d_0 \\ lE_{elec} + l\varepsilon_{amp}\, d^4 & ,d >= d_0 \end{cases} \quad (1)$$

Notations used in the (1) are defined as follows:

ε_{fs} : Energy consumption of transmission.

ε_{amp} : Energy consumption of amplification circuit.

d : Transmission distance.

d_0 : the threshold of Transmission distance for the amplification circuit.

$$d_0 = \sqrt{(\varepsilon_{fs}/\varepsilon_{amp})} \quad (2)$$

L: the length of transmission packet

Usually, the distance between CH and cluster member nodes is less than d_0 but the distance between sink and CH is more than d_0.

Energy consumption to receive procedure is calculated as:

$$E_{RX}(l) = E_{RX\text{-}elec}(l) = lE_{elec} \quad (3)$$

In addition, CH receives data from its cluster member nodes and transmits received data to the sink. CH performs the data aggregation and its energy consumption is equal to EDA. Beside the above parameters that has been used in the proposed algorithm, other two parameters, namely ECSN and ECS are defined which indicate needed energy to determine new CH. Values of these parameters are determined by the proposed algorithm.

IV. PROPOSED CLUSTERING METHOD

A. Partitioning

It is an NP problem to calculate the optimal number of CH in a set of nodes. Simulated annealing algorithm has been considered as a good method for complex nonlinear optimization problems. Assume that the rate of the optimal number of CH to the total number of nodes is R. sink determines this parameter using simulated annealing algorithm, then sends this parameter together with its coordinate (x, y) and EL (Energy Level) to all nodes in the form of a packet. Using the received packet, nodes acquire the number of partitions which is equivalent to T^2.

R: rate of cluster optimal selection

n: number of nodes

$$T=\lfloor \sqrt{(R^*n)} \rfloor \qquad (4)$$

D=A/T ; Length/Width of each partition

In this case, square area is divided into T*T equal parts and Fig. 1 shows an example for r=0.1 and n=100. So, calculated T is equal to 3.
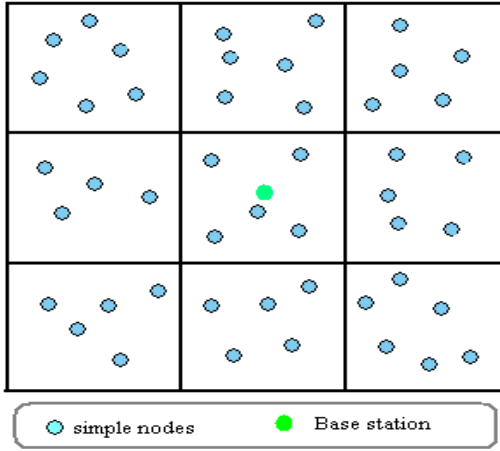

Fig. 1. Sensor nodes are wide spread in area

Each node should be able to recognize the partition that is located. In order to nodes execute following pseudo code.

```
Switch (node coordinate)
{
Case1:   if (x<D & y<D)
   Node coordinate='1';
Case2:   if (D<x<2D & y<D)
   Node coordinate='2';
Case3:   if (2D<x<3D & y<D)
   Node coordinate='3';
……
Case  T²:   if ((T-1)*D<x<T*D & ((T-1)*D<y<T*D)
   node coordinate=T²;
}
```

Fig. 2. Pseudo code for determining partition

B. Selecting CH

After partitioning, each node can determine partition which is present. To elect a new CH inside a partition, exiting nodes send basic information in the form of a packet which is determined with one of the proposed methods in the following. In this paper, different parameters to select CH have been considered and each of them shows different results in selecting CH and lifetime of network. In more detail each of them is expressed.

1) Nodes with Maximum energy

One of the criteria to choose CH is the remaining energy of each node is assigned ME, AME. Considering that energy consumption in the data transmission is calculated from (1).Therefore, the remaining energy is proportional to geographical position and distance of each node to the sink. So that different nodes have different energy level. Fig.3 has shown the data packet transmitted between nodes in this method.

ID	Remaining Energy

Fig. 3. Packet of ME

In the first round all nodes have equal energy. Therefore, CH is randomly selected but in the next round will be selected nodes with the highest energy which network overhead will be increased by selecting CH in each round. In this case, each node consumes energy equivalent to the ECS which is calculated by (5) and it causes reduced life time of wireless sensor network. To prevent this problem, we introduced a parameter called EL (Energy_Level) and it has been sent through the sink to all nodes in the partitioning. When the remaining energy of CH is less than EL in a partition, CH selection stage will be resumed with the highest energy again.

$$E_{cs}=(N/T)(E_{tx}*l*(A/t)*((\sqrt{2})/2)*(A/t)*((\sqrt{2})/2)) \qquad (5)$$

Equation (5) is obtained by (1) that average number of nodes in each partition is N/T^2 so that each nodes need to send $(N/T^2)-1$ packet to own neighbors in partition which are consumed Ecs.

2) Nodes with Minimum distance to sink

The next effective parameter to improve network lifetime is nodes distance to sink is assigned by MB, AMB. Whatever distance to sink is less amount of energy consumption will be less. CH has an obligation to transmit data from its member nodes to the sink. Thus uses less energy to perform this task by this method. This method does not need to select CH in each round so that the overhead is decreased. Fig. 4 has shown the data packet transmitted between nodes in this method.

ID	Distance To BS

Fig. 4. packet of MB

Disadvantage of this method is early death of nodes which are close the sink in each partition. EL is used to solve this problem. When energy level of any CH is lower than definite EL, the other node in that partition selects as CH. Also EL parameter can solve coverage problem.

3) Nodes in the center of partition

Other parameter has relationship increased network lifetime is distance to center of partition station is assigned by MC, AMC. In order to obtain balanced distribution of energy consumption in each partition, it is better nodes have the same distance to CH in a partition. Thus nodes will be selected as CHs when they are almost in the center of partitions. The data packet transmitted between nodes in this state is as like as previous method but we use distance to center of each partition instead of distance to sink field.

Disadvantage of this method is early death of nodes which are in the center of each partition similarly prior method. EL is used to solve this problem, again.

4) Nodes with Minimum distance to sink and Maximize energy

This method is as like as selecting nodes with minimum distance to sink method that has been previously explained but in this case is inspected the residual energy of CH candidate to elect CH, too. This method is assigned by MBME, AMBME. Fig.5 has shown the data packet transmitted between nodes and (6) shows how distance and remain energy combine together.

ID	Energy	distance of BS

Fig. 5.Packet of MBME

$$S_{parameter}=\alpha*(E_{remain}/E_{max})+\beta*(distance_{BS}/distance_{max}) \qquad (6)$$

Another parameter to elect CH is AMCME, AMC as the same as before now and Energy parameter is added on it. This method is as like as AMBME and simulation result has shown in table II. In all above proposed methods clusters are fixed and just CHs change in their partitions.

After that, CH is determined with each of the above proposed methods; CHs broadcast an 8-bit packet to all neighbor nodes in its partition to introduce it as CH that energy consumption is equivalent to Ecsn in each CH.

V. PERFORMANCE EVALUATION

In this part, we suppose network model has been described in part 3 to evaluate purposed method together and previous works that is uniformly distributed 100 nodes in 150 m*150m square area. Rounds have been observed until all nodes are dead in simulation environment. TABLE I has shown energy consumption to transmit data has been used in simulation.

TABLE I: ENERGY CONSUMPTION MODEL

Parameter	Value
Transmitter/Receiver Electronics	E_{elec}=50nj/bit
Transmit Amplifier if destination to BS<=d0	ε_{fs}=10pJ/bit/m^2
Transmit Amplifier if destination to BS >=d0	e_{amp}=0.0013 pJ/bit/m^4
Initial energy of each node	0.5J
Data Aggregation	E_{da}=10 nj/bit/message
Message size	4000 bits

Simulation results have been shown in Fig. 6 for each partition that has selected CH by method '1' in section 4.B. Although, LEACH algorithm makes network load balancing but the network will be destroyed when all nodes die almost simultaneously. The proposed method without EL has results like LEACH although using EL parameter increase network lifetime but first node death occurs earlier than LEACH method because of a node remains a CH until residual energy of that node to be EL. In this case overhead of CH selection not be imposed on network in each round and total number of CH selection is reduced. Fig. 6 shows the results obtained from LEACH is similar to ME method but ME_EL method offers a much better result than both diagram.
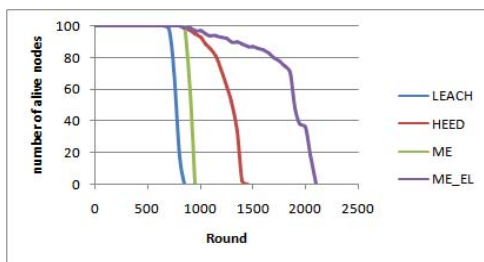

Fig. 6. Simulation result of ME method

Fig. 7 shows simulation result to select CH in each partition obtained by 4. B.2 method.

Although MB method increases network lifetime but the

first node death occurs more quickly .in this method, node that is selected as the CH are active whenever their life. Thus, the network loses all nodes near the sink in each partition. MB_EL procedure delays death of first node but prolongs network lifetime due to overhead CH selection. In this case, if the first node's death is important in the network we propose MB_EL and for better network lifetime MB is suitable.

Simulation results of proposed method in 4.B.3 is the same as shown in Fig. 7 but comparing with 4.B.2 method death of nodes occur uniformly in whole network and alive nodes cover more area.
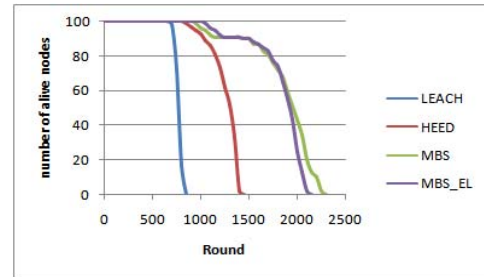

Fig. 7. Simulation result of MB method

In 4.B.4 procedure in addition to using minimum distance to sink is added energy parameter, too. In spite the early death of first node in MBME strategy, network lifetime is more than LEACH.
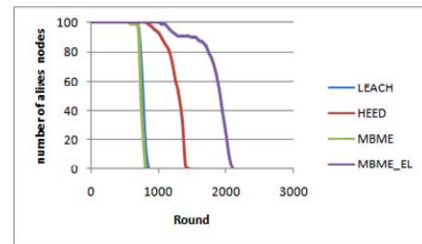

Fig. 8.Simulation result of MBME method

Fig. 8 shows network lifetime is decreased by using two parameters to select CH thus all nodes transmit energy parameter and their distance to the sink to each other. But simulation shows this simple partitioning and hypothesis have result as like as LEACH protocol. When EL parameter applies to limit CH selection network lifetime prolong due to decrease energy consumption to select CH and first node death happen later.

As result shows using EL parameter can improve most of proposed method to compare more clearly Fig. 9 shown it. Network longevity of MB and MC method is more than MB_EL and MC_EL due to increase CH selection but using EL parameter can enhance network coverage.
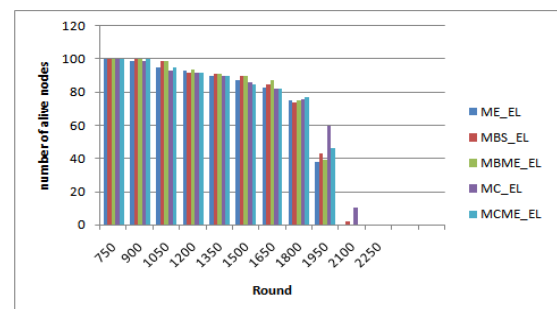

Fig. 9.Simulation result of EL parameter

VI. CONCLUSION AND FUTURE WORK

Clustering is a good strategy to safe energy consumption in wireless sensor networks. This paper has surveyed different method on partitioning model to prolong lifetime of network. Simulation result shown using EL method to decrease clustering operation is efficient for future plan we estimate amount of EL parameter to improve network lifetime. And so on we survey security and resistance of clustering against different attack.

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