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Energy Efficient Hierarchical Unequal Clustering in Wireless Sensor Networks

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Abstract

Energy efficient modeling is a major issue in the wireless sensor network. The main solution for energy efficient routing is by means of clustering. This paper proposes an unequal clustering approach in the networks for even energy distribution. It also reduces the overall energy consumption which in turn improves the network lifetime. The simulation is carried out in MATLABR2010a. The energy needed for entire operations for one round using the proposed method is lesser than that of LEACH, an equal clustering methodology.

Keywords: Clustering, Energy Efficient, Unequal Clustering

1. Introduction

Wireless Sensor Networks are extremely dispersed networks of small, light weight Wireless Sensor Nodes (SN). The network can be classified as homogeneous or heterogeneous type. The homogenous network is built upon with the nodes of same capability, whereas in heterogenous of different capable nodes. Mainly these sensors are used to observe the environment based on the desired physical parameters. Some of the real time applications of WSN are climate monitoring, solar monitoring, power plant monitoring, industrial measurements, and resource monitoring and event detections.

Most of the WSNs have been designed in such a way that the nodes sensing the environment transmit its generated data to the Central BS (BS). In this case, energy consumption is high when all nodes communicate directly with the BS. Clustering promotes a way of transmitting data to the BS using multiple hops[1]. In clustering, CH nodes (CH) collect the information from its members and aggregate it. Only CH nodes forwards those aggregated information to the BS. This approach definitely mitigates the overall energy consumption.

In general, clustering[2] can be classified into equal and unequal clustering. Equal clustering ensures the same number of cluster members for all the clusters. All CH nodes communicate with the BS in a multi-hop manner through other CH nodes. The CH nearer to the BS finally relay all the gathered information to the BS. In this case there may be a chance for those relay CH nodes to die early. To avoid this situation unequal clustering has been proposed.

The paper is organized as follows: In section 2, works related to unequal clustering is briefly enlightened. In section 3, the proposed algorithm is explained in detail. In section4, the proposed protocol HUCA is compared with LEACH. The comprehensive evaluation outcomes are mentioned.

2. Related Works

There are several clustering methodologies have been proposed for wireless sensor networks. Some of them are discussed below:

2.1 LEACH

LEACH[3] utilizes an equal clustering methodology. The network is divided into Clusters. LEACH elects the CH node based on local decisions. CH has been chosen

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at random based on some threshold value. Based on the threshold on every round the CH nodes have been chosen. The CH node collects the information from the ordinary nodes in its cluster. CH aggregates the data before forwarding to BS. In LEACH, there may be a chance of selecting a lower energy node as CH nodes.

2.2 HEED

Hierarchical Energy Efficient Distributed Clustering[4] considers the remaining energy level of SNs for the stochastic selection of CH nodes. The degree of the CH nodes or average distance to its nearby neighbor nodes is used to conclude the cluster-head when two nodes are competing for CH. HEED provides a better performance than LEACH.

2.3 LCC

The improved version of LEACH is LEACH-Centralized with Chain (LCC). LCC[5] forms a super cluster with the CH nodes as its members. CH nodes are selected by the same procedure as LEACH. This protocol chooses one leader among super cluster members. By means of greedy approach, it builds a chain connection between the super cluster members to BS via the leader. Super CH Leader aggregates the data from CH nodes. Finally, the super CH Leader sends the aggregated data to the BS directly.

2.4 EEGTP

In Energy Efficient Graph Theory Protocol[6] for WSN, all the CH nodes communicate with the BS in multi hop manner. The last node in the multi hop communication named super aggregator gathers all the data from CH nodes and finally send it to the BS.

2.5 CHEF

CH nodes Election using Fuzzy logic is an unequal clustering protocol[7] which selects the cluster in a centralized manner. BS is involved in the selection process. This protocol uses three fuzzy descriptors such as node concentration, residual energy and node centrality for electing the CH. BS creates fuzzy rules and computes the crisp output representing the chance for CH.

2.6 EECDC

Energy Efficient Coverage Aware Data Collection[8] in Wireless Sensor Networks first forms the MIS and then selects the effective SH. Communication is divided into inter and intra setups. Intercommunication is handled by using multi hop between SH to BS.

2.7 EEUC

Energy Efficient Unequal Clustering[9] uses a probabilistic approach to choose the tentative CH. Tentative CH nodes participate in the CH competition. EEUC considers the node's residual energy for CH selection.

2.8 EAUCF

Energy Aware Unequal Clustering using Fuzzy logic[10] deals with unequal clustering uses multi hop routing. Unequal clustering delays the first node die time when compared to equal clustering used in LEACH. Fuzzy rules are utilized for selecting the coverage distance of CH nodes based on three input variable distances to the BS, residual energy and node degree. Moreover it combines the advantages of unequal clustering and fuzzy logic approaches.

2.9 IFUC

In the protocol Improved Fuzzy Unequal Clustering[11], the input fuzzy descriptors for each node are its distance to BS, energy level and local density. The probability of nodes becoming CH and its radius is calculated as output fuzzy parameters using if- then rules. After that, ACO technique is to produce the energy-efficient route between CH nodes and BS in multi hop manner.

2.10 DSBCA

Uniform clustering may lead to unbalanced load for CH nodes nearer to the BS because of load due to relaying. To balance the load , Distributed Self Organization Load Balanced Clustering Algorithm[12] helps to provide a non uniform clustering. Hierarchical arrangement of clusters is created. The distance from the BS and connectivity density is used to calculate the coverage radius of each CH. The nodes within the coverage radius become members of that cluster.

3. HUCA Algorithm Preliminaries

For the configuration of the network, the preliminaries are defined below:

- All nodes are stationary after deployment.
- All nodes know its location using GPS receivers.
- The network is of homogeneous type.

- All SNs have same initial energy.
- The BS is located away from the field area to be monitored.

3.1 Radio Model

The free space radio model is used to calculate the energy in free space. Eq. 1 characterizes the amount of energy needed for forwarding 'l' bit of data to a node at a distance d. Eq. 2 stands for the energy needed to receive 'l' bit of data.

$$E_{tx}(l,d) = l^* E_{ele} + l^* e_{fs} d^2 \quad (1)$$

$$E_{rx}(l) = l^* E_{ele} \quad (2)$$

E_{ele} → Energy Consumption/bit in transceiver circuit.

e_{fs} → Energy degenerated/bit in RF amplifier

3.2 Proposed Algorithm

The proposed algorithm is as follows: Hierarchical Unequal Clustering Algorithm (HUCA) is based on unequal clustering. It uses the local knowledge to form clusters and selecting the CH nodes. HUCA is divided into three phases. They are,

i. Grid formation
ii. CH node election
iii. Data collection

3.2.1 Grid Formation

Network area is separated into three horizontal grids based on the longitudinal distance from the BS. The grid located near to the BS will be having more number of CH nodes which guarantees the uniform energy consumption among the CH nodes. In equal clustering the nearby CH nodes to the BS involves high data traffic which costs its lifetime.

Grid formation phase

```
Network Area = 100 * 100
Levels = 3
Y ← longitudinal axis
If Y < /3 then
        L1 ← for all Ni(X,Y)
Else if Y < 2*(100/3) then
        L2 ← for all Ni(X,Y)
Else
        L3 ← for all Ni(X,Y)
```

3.2.2 CH Nodes Selection Phase

Since the network is homogeneous in nature the initial CH node selection will be a random selection. Each node will choose a number in the range 0 to 1. The node having the highest value among its neighbor will elect itself as the CH node and broadcast its selection to the nearby nodes. After receiving this selection messages from one or more CH nodes, the ordinary nodes join the nearby CH node. In the next CH node selection phase the node having the higher remaining residual energy will be elected as the CH nodes.

CH nodes election

```
Set number of clusters 'n' in each level
For  i = 1:3
For  j =1:n
Randomly choose one node N_ij
CHlist ← N_ij
CMlist ← all nodes N except CH
If N_ij = CM then
Sends joinCHmsg(N_ij(ID)) to nearby CH
Else
Accepts the joinCHmsg() from N_ij(ID)
End
End
End
```

No. of nodes in each cluster vary because it is based on the communication range of the head.

3.2.3 Data Collection

The nodes transmit its data to its CH nodes in the respective grids. The CH node aggregates its member node's data and forwards it to the next grid CH node which is nearer to its location. Thus the CH nodes in the grid close to BS acts as router nodes to their higher level grid nodes. Also the rapid energy depletion of CH nodes nearby BS is avoided by increasing their number.

4. Simulation and Result

MATLAB R2010a is used to simulate the proposed algorithm HUCA. The network setup is shown in the Figure 1. Each node is identified by its unique ID. The network region is divided into 3 horizontal grids. The network parameters are stated out in Table 1.

Energy needed for one round is calculated by the proposed algorithm. Figure 2 compares HUCA with LEACH. HUCA proves that the energy needed for one data collection round is 11% less than the energy needed for the same using LEACH.

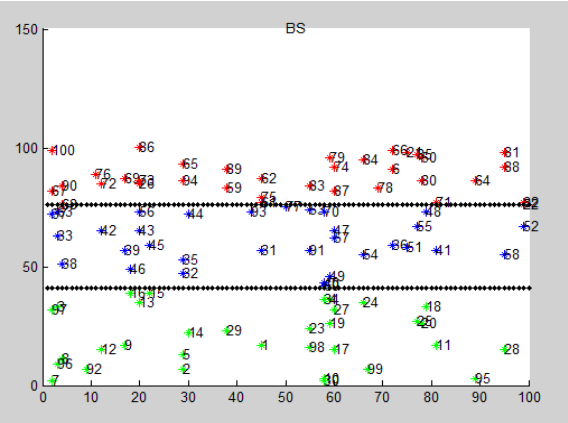

Figure 1. Wireless Sensor Network of 100 nodes.

Table 1. Simulation parameters

Parameter	Value
Network size	100 * 100 m
BS location	(50,150)
Number of nodes	100
Packet size	4000 bits
Initial energy	1 J
E_{ele}	50 nJbit^{-1}
Θ_{fs}	10 pJbit^{-1}
E_{agg}	50 nJbit^{-1}

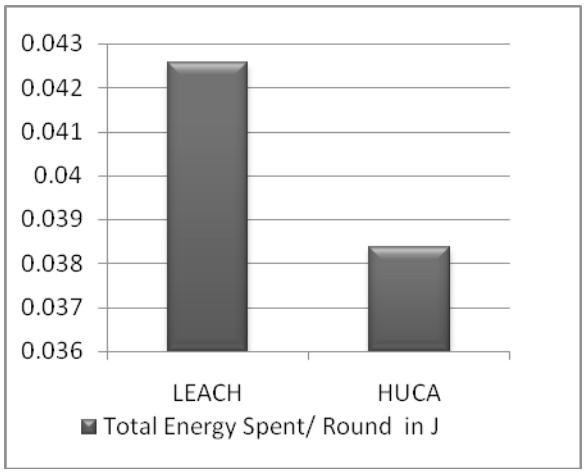

Figure 2. Comparison of LEACH and HUCA.

LEACH follows an equal clustering. Number of nodes in each and every cluster is same. This is depicted in the Figure 3. Using HUCA the above network setup is divided into 3 horizontal grids. Again it is subdivided which results in total of 16 unequal clusters. Figure 4 shows the 16 clusters and its number of nodes.

Figure 5 shows the energy consumption of 10 clusters using LEACH protocol. The energy consumption of 16 clusters in HUCA algorithm is shown in Figure 6.

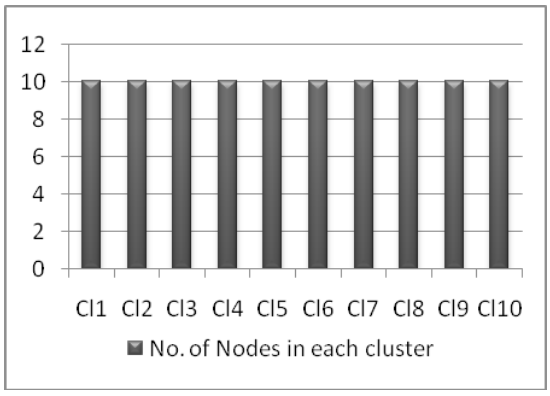

Figure 3. Equal clustering in LEACH.

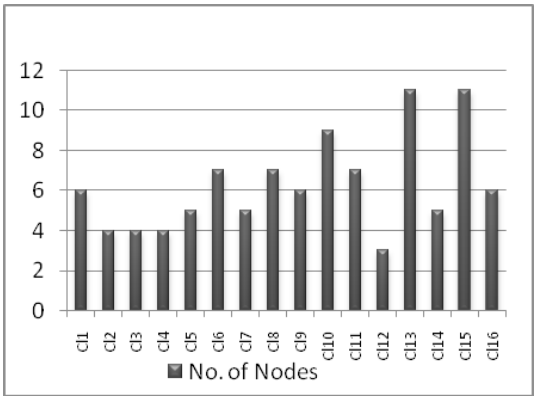

Figure 4. Unequal clustering in HUCA

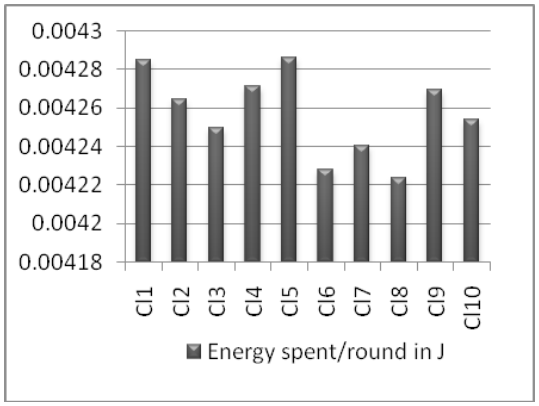

Figure 5. Energy consumption in LEACH.

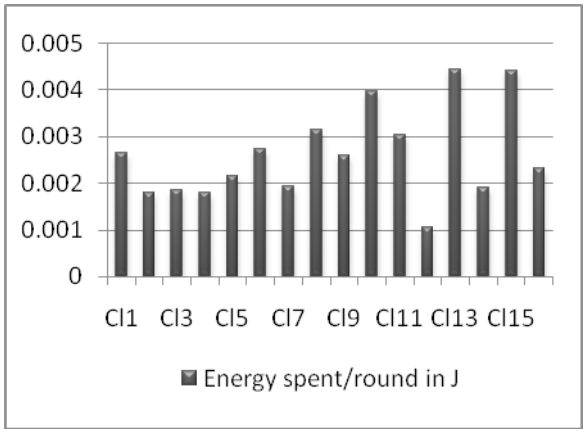

Figure 6. Energy consumption in HUCA.

5. Conclusion

The network area is divided into hierarchical layers and clusters are formed in each layer. Communication happens between CH nodes and a BS in a multi hop fashion which uses CH nodes as relay nodes. This proves more energy consumption when compared to the equal clustering LEACH protocol.

6. References

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