MULTI-LEVEL ENERGY EFFICIENT IMPROVED UNEQUAL CLUSTERING IN WIRELESS SENSOR NETWORKS

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ABSTRACT

In wireless sensor networks (WSNs), the node distribution in the unequal clustering is rapidly used for distributing the load and increase the network lifetime. In tradition unequal clustering mechanism, the nodes which are nearer to the base station suffers with energy depletion. To overcome this issue, this paper proposes the multilevel unequal clustering algorithm with efficient cluster head selection procedure based on the residual energy and maximum transmission capacity of the nodes. The proposed algorithm uses threshold function to resist the waiting time of the node for receiving the cluster head notification message. The simulation results show the efficiency of the proposed algorithm compared with the counterpart algorithms.

Keywords: Multilevel clustering, Wireless sensor networks, Clustering, Energy consumption.

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1. INTRODUCTION

The major development in the field of sensor devices led to the development of wireless sensor networks. The applications of WSNs are environmental monitoring, disaster management, defence, health care and many more [1]. The WSNs are having large number of sensor nodes which are deployed in the remote regions to cover wider areas. The functionality of the sensor nodes is to collect the sensing data, process and transmit to the base station. The base station is connected to the internet which publishes the data. In many cases, sensor nodes are having limited battery power. It is difficult to replace the sensor nodes once it is deployed in the region

after depletion of the power. Therefore, minimizing the energy consumption and improving the network life time is the major factor in WSNs. In [2], many issues are addressed in this research area. The cluster based energy efficient mechanism is one of the approaches to address the energy issue. The sensor nodes are divided in to clusters and forms one cluster head for each group. In some conditions, the sensor nodes with high energy are selected as cluster head [3-4]. Each sensor nodes represents only one single cluster senses the local data and forwards to the cluster head. The cluster head aggregates the collected data and process the data to the base station. Figure 1 shows the wireless sensor network model. Clustering is the suitable mechanism to improve the network lifetime by framing the different groups [5]. The clustering can be done in WSNs by using two different methods. One is centralized approach and another one is distributed approach. In the centralized approach, the selection of cluster head is done by base station as predefined by the defined application. In the distributed approach, the sensor node elects the cluster head based on the algorithm.

Figure 1 Structure of Wireless Sensor Networks

Many algorithms are proposed with different objectives such as load balancing, fault tolerance, increasing network lifetime and minimizing the data duplications etc. [6]. This paper develops the clustering based energy efficient mechanism for WSNs. The rest of the paper is organized as follows. Section 2 explains about the related work which deeply concentrates on energy efficient routing protocols. Section 3 explains about the network model, energy model and level based mechanism for unequal clustering. Section 4 explains about the proposed energy efficient improved unequal clustering algorithm. Section 5 deals with the simulation analysis and finally the conclusion is drawn in section 6.

2. LITERATURE SURVEY

The main aim of this study is to increase the network lifetime and to decrease the energy consumption of the nodes. The deployment of the nodes in the distributed environment is a challenging task [7]. In [8], the energy efficient algorithms are proposed for cluster based routing. This mechanism uses cluster head rotation process to distribute the consumption of energy over all nodes. The major drawback of this protocol is that there is a chance of selecting the low energy nodes as cluster heads and allows the nodes distribution in the network is not in the uniform manner. In [9], the HEED (Hybrid Energy Efficient Distributed Protocol) was

proposed to overcome the drawbacks of the LEACH algorithm. The selection of the cluster head is based on the residual energy of the nodes. Therefore, the nodes which having the highest energy will become the cluster heads. The limitation of this protocol is the node which is nearer to the base station will suffer more load due to the incoming packets from the other clusters.

In [10], the authors proposed the unequal clustering algorithm to overcome the limitations of HEED. The main approach of this protocol is to restrict the cluster size which is near to the bases station. This mechanism preserves the energy of the cluster head nearer to the base station. However, the nodes nearer to the BS affected with imposed traffic and increased overhead. In [11], weight based rotation mechanism (WEERC) was proposed to select the cluster heads. This mechanism consists of two steps. As an initial step, the CH candidates are selected based on the parameters such as degree of the node, transmission range and residual energy. In the next step, the CH candidates compete with in themselves to become final cluster head based on the available neighbouring nodes with in the transmission range. The proposed routing algorithm uses the rotation process with in the cluster. This process will continue until all the nodes drain their energy.

In [12], the weight driven cluster head selection process was proposed to select the cluster head. The cluster head selection is based on the three metrics such as node distance, frequency of cluster head and remaining energy. The cluster head which falls short below the threshold will be removed as the CH and the next node which having the highest weight become the cluster head. In [13], the authors proposed dynamic load balancing protocol for WSNs. This protocol selects the CH based on the highest remaining energy with in the network. The clusters formations in the network are formed in unequal manner. If the CH energy reached below the threshold, the base station rearranges the cluster of the network. In [14], the hybrid routing protocol is proposed by combining rotation protocol and HEED protocol. This protocol uses rotation mechanism inside the cluster to select the CH.

3. PRELIMINARIES

3.1. Network Model

This paper considers the following assumptions: X sensor nodes are deployed randomly in to $K \times K$ dimension region. The Base station is situated outside the sensing region. The x_i nodes are acted as cluster heads where $x_i \in X$, M clusters are formed and $x_i \in M$, the M are defined as $M = (M_1, M_2, M_3, \dots, M_n)$. The following are the network assumptions for the base station and sensor nodes.

- The sensor nodes deployed in the network are heterogeneous in terms of energy, but they have similar processing capacity, computation capacity and communication capacity.
- The sensor nodes have the energy constraint but not for the base station.
- The sensor nodes are fixed throughout the lifetime of the network and randomly deployed in the regions.
- All sensor nodes are available within the range of the base station to form the clustering process.

3.2. Energy Consumption Model

To evaluate the energy consumption of the network, we used the Heinzelman et al. [15] model. Figure 2 shows the energy consumption model of the communication.

Figure 1 Energy Consumption model of the communication

The transmission energy for β bit packet for a distance of d between two nodes is given by equation 1.

$$E_{Tran}(\beta, d) = \begin{cases} \beta E_e + \beta \varepsilon_f d^2, & \text{where } d < d_0 \\ \beta E_e + \beta \varepsilon_a d^4, & \text{where } d > d_0 \end{cases} \quad (1)$$

$$d_0 = \sqrt{\frac{\varepsilon_f}{\varepsilon_a}} \quad (2)$$

The receiving energy for β bit packet is given by equation 3.

$$E_{Rec}(\beta) = \beta E_e \quad (3)$$

Where β is the number of bits, E_{Tran} is the transmission energy and E_{Rec} is the receiving energy, d is the distance between the nodes. E_e , E_f , E_a are the coefficients of the energy consumption model.

4. PROPOSED ALGORITHM

4.1. Unequal Clustering Algorithm for WSNs

In WSNs, the energy limitation is the major concern to increase the network lifetime. To overcome this issue, energy consumption of the nodes must be managed efficiently. The property of the cluster head is to manage the energy consumption of the nodes in homogeneous networks. Though, there are many algorithms addressed the energy issue in WSNs, still it is not completely achieved. The rotation of cluster heads somewhat balances the energy consumption of the CHs and member nodes and hardly fulfils the objective in the inter-cluster communication. The nodes nearer to the base station deplete the energy quickly due to the packets coming from the nodes located far from the base station.

The clusters around the base station should be in smaller size. This is due to the CHs consumes high energy with in these clusters. Therefore, more number of clusters needs to be formed around the base station. The formation of the clusters nearer to the base station is done by considering range of the node's competition radius. Consider that $L_{\max}$ is the highest computation radius of the node which is directly proportional to the distance between the base station and competition node. Let node 'i' is the competing node for CH and it calculates the competing radius L_i by considering the distance from the base station which is given in Eq 4.

$$L_i = (1 - \lambda \times \frac{d_{\max} - d(x_i, BS)}{d_{\max} - d_{\min}}) \times L_{\max} \quad (4)$$

Where $d_{\min}$ is the distance from the node which is located nearer to the base station, $d_{\max}$ is the distance from the node which is located farthest from the base station. λ is the constant value which lies in between 0 and 1, $d(x_i, BS)$ is the distance from the node 'i' to the base station.

Figure 2 Overview of the proposed algorithm

From the Figure 2, it is observed that the nodes are placed in the different regions of the network. The transmission range of the network is given as $T_{\max}$ and $T_{\min}$. The node needs to find their levels in the network by applying the Eq 5.

$$x_{level} = \frac{d(x_i, BS) - X_{T_{\max}}}{X_{T_{\max}} - T_{\min}} \quad (5)$$

At the time of cluster head selection, each node forwards their residual energy to the neighbouring nodes with in the radius. The node which is having the highest residual energy is selected as CH for particular round. This process will avoids the selection of two or more cluster heads in the same cluster. However, the cluster head selection process consists of two stages. In the first stage, all nodes broadcast the bid to become the cluster head. In the second stage, the nodes select the cluster head based highest residual energy and shares the information to the other nodes with in the transmission radius.

4.2. Energy Efficient Improved Unequal Clustering Algorithm (EEIUC)

The proposed Energy Efficient Improved Unequal Clustering Algorithm removes the first step in CH selection process performed in general procedure of unequal clustering algorithm.

In the initial stage, the base station performs the first step by broadcasting the NEW_MSG which contains the $d_{\min}$ and $d_{\max}$. Every node in the cluster has to forward the message and the time limit for receiving the message is given in Eq. 6.

$$\tau(i) = \eta \times \tau_{\text{delay}} \quad (6)$$

Here η is the random number which lies in between 0 and 1, τ_{delay} is the time delay to receive the message from the other nodes. At the initial round, the energy of all nodes is in equal level. Therefore η can be set in between 0 and τ_{delay} . The node which doesn't receive the NOTIFY_MSG before the τ_{delay} expires, it claims himself as the CH to the cluster for the initial round and forwards the information to all the neighbouring nodes within the transmission range which has been given in Eq. 4. This mechanism reduces the exchange of messages between the nodes at the time of cluster formation.

The sensor nodes in the network find the cluster head and send the JOIN_MSG. For the next rounds, EEIUC performs the same operation except the τ_{delay} . Algorithm 1 shows the cluster formation in EEIUC algorithm.

Algorithm 1: Cluster formation in EEIUC algorithm

```

Input: BS_ID<- Base Station ID,
      Tmax<- maximum transmission range
      Tmin<- minimum transmission range
Begin
1: Base station broadcasts the MSG with information of BS_ID
2: for each  $x \in X$  do
3:    $x \leftarrow d(x_i, \text{BS})$ 
4:    $x \leftarrow x_{\text{level}}$  by computing Eq. 5
4: end for
5 if  $x_{\text{level}} < \text{threshold}$  then
6:  $x_i \leftarrow \text{Level1}$ 
7: else
8:  $x_i \leftarrow \text{Next level}$ 
9: end if
End

```

Algorithm 2 shows the cluster head selection process where each node competes to the position of cluster head by sending the residual energy information to the all nodes within the transmission range.

Algorithm 2: Cluster Head Selection Algorithm

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Begin
1: BS Broadcasts the NEW_MSG
2:  $x_i$  receives the NEW_MSG and initiates timer  $\tau(i)$  based on their residual energy

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3: if  $x_i$  receives NOTIFY_MSG before  $\tau(i)$  expires then
4:    $x_i$  cancels  $\tau(i)$  and waits for another nodes NOTIFY_MSG
5: else
6:    $x_i$  declares itself as the CH and broadcasts the NOTIFY_MSG to all nodes
7: end if
8: if  $x_i$  is not selected as the cluster head then
9:    $x_i$  joins the cluster based on the algorithm 1
10: else
11:    $x_i$  waits until it receives JOIN_MSG
12: end if
End

```

5. SIMULATION SETUP

The simulation is carried out using the Qual Net 6.1 [16] simulator. 200 nodes are deployed in the region of $1000 \times 1000 \text{ m}^2$. The nodes are distributed non-uniformly in the network. Table 1 shows the parameters for the simulation. To identify the effectiveness of the proposed protocol, we considered the HEED [9] and EC [17] protocols.

Table 1 Parameters for simulation of EEIUC algorithm

Parameter	Value
No. of Nodes	200
Network Region (m^2)	1000×1000
Packet Size (bytes)	200
Initial Energy of nodes (J)	0.5-1.5
E_e (nJ/bit)	50
E_a (pJ/bit/ m^4)	0.0013
E_f (pJ/bit/ m^2)	10
$L_{\max}$ (m)	110

The results of the simulation are carried out with several metrics which are given below:

- Average energy consumption: This evaluation metric is defined as the all nodes average energy consumption in the network for single round.
- Network residual energy: This is as the total residual energy of the network for single round.
- Network Life time: This is defined as the time taken for first node dies in the network.
- Number of nodes alive: This shows how many numbers of nodes are alive in the network after simulation time is completed.

5.1. Energy Consumption

The energy consumption of the EEIUC protocol is compared with HEED and EC protocols. Figure 3 shows the average energy consumption of the network for single round. It is observed that the energy consumption of the EEIUC protocol is slightly less compared to the HEED and EC protocols. It is due to the proposed EEIUC eliminates the first step in the process of CH selection by avoiding the broadcasting of bids to elect as CH. The HEED and EC follows the bid procedure for the selection of Ch. Therefore, the average energy consumption of the network of EEIUC is less.

Figure 3 Average energy Consumption Vs Number of Nodes

5.2. Network Residual Energy

Figure 4 represent the average residual energy of the network in EEIUC with respect to the number of simulation rounds. It is identifying that the residual energy of the nodes in the network is reduces at the common rate in EEIUC, HEED and EC protocols. In EEIUC, the nodes which are present in the layer 1 consume more energy due to their presence nearer to the BS. The other protocols such as HEED and EC also consume more energy due to their network behaviour.

Figure 4 Average Residual Energy of the Network Vs Number of Rounds

5.3. Network Life time

Figure 5 shows the network life time in EEIUC, HEED and EC protocols. It is observed that the Network lifetime of EEIUC is higher compared to the HEED and EC protocol. The proposed EEIUC protocol uses time delay mechanism to select the CH. It reduces the waiting time and

energy consumption of the node compared to the HEED and EC protocol. Therefore, the residual energy of the nodes will be high.

Figure 5 Network life time in EEIUC, HEED and EC when first node dies

5.4. Number of Nodes Alive

Figure 6 shows the number of nodes alive when the number of rounds progress in EEIUC, HEED and EC. It is observed that the EEIUC shown improved performance compared to the remaining protocols. EEIUC recorded 18% improvement in terms of number of nodes alive compared to the HEED and 21% improvement compared to the EC routing protocol.

Figure 6 Number of Alive Nodes Vs Number of Rounds

6. CONCLUSION

This paper presents the Energy Efficient Improved Unequal Clustering Algorithm (EEIUC) for wireless sensor networks. The proposed algorithms eliminate the procedure of bidding for the selection of CH in the cluster. EEIUC allows the level based mechanism to improve the lifetime of the network by managing the nodes which are nearer to the base station. The simulation of the proposed protocol is carried out using the four metrics such as energy consumption, network lifetime, number of alive nodes and network residual energy. The proposed protocol proved their efficiency while comparing with HEED and EC protocols.

REFERENCES

- [1] Rao, PC Srinivasa, and Haider Banka. "Novel chemical reaction optimization based unequal clustering and routing algorithms for wireless sensor networks." *Wireless Networks* 23, no. 3 (2017): 759-778.
- [2] Sabor, Nabil, Mohammed Abo-Zahhad, Shigenobu Sasaki, and Sabah M. Ahmed. "An unequal multi-hop balanced immune clustering protocol for wireless sensor networks." *Applied Soft Computing* 43 (2016): 372-389.
- [3] Xia, Hui, Rui-hua Zhang, Jia Yu, and Zhen-kuan Pan. "Energy-efficient routing algorithm based on unequal clustering and connected graph in wireless sensor networks." *International Journal of Wireless Information Networks* 23, no. 2 (2016): 141-150.
- [4] Wu, Dapeng, Jing He, Honggang Wang, Chonggang Wang, and Ruyan Wang. "A hierarchical packet forwarding mechanism for energy harvesting wireless sensor networks." *IEEE Communications Magazine* 53, no. 8 (2015): 92-98.
- [5] Zhang, De-gan, Si Liu, Ting Zhang, and Zhao Liang. "Novel unequal clustering routing protocol considering energy balancing based on network partition & distance for mobile education." *Journal of Network and Computer Applications* 88 (2017): 1-9.
- [6] Malathi, L., R. K. Gnanamurthy, and Krishnan Chandrasekaran. "Energy efficient data collection through hybrid unequal clustering for wireless sensor networks." *Computers & Electrical Engineering* 48 (2015): 358-370.
- [7] Gupta, Vrinda, and Rajoo Pandey. "An improved energy aware distributed unequal clustering protocol for heterogeneous wireless sensor networks." *Engineering Science and Technology, an International Journal* 19, no. 2 (2016): 1050-1058.
- [8] Wu, Dapeng, Jing He, Honggang Wang, Chonggang Wang, and Ruyan Wang. "A hierarchical packet forwarding mechanism for energy harvesting wireless sensor networks." *IEEE Communications Magazine* 53, no. 8 (2015): 92-98.
- [9] O. Younis and S. Fahmy. "HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks," *IEEE Trans. Mobile Computing*, vol. 3, no. 4, Oct 2014, pp. 366–79.
- [10] Darabkh, Khalid A., Noor J. Al-Maaitah, Iyad F. Jafar, and Khalifeh Ala'F. "Energy efficient clustering algorithm for wireless sensor networks." In *2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 590-594. IEEE, 2017.
- [11] Huang, Jianhua, Yadong Hong, Ziming Zhao, and Yubo Yuan. "An energy-efficient multi-hop routing protocol based on grid clustering for wireless sensor networks." *Cluster Computing* 20, no. 4 (2017): 3071-3083.
- [12] Wu, Dapeng, Jing He, Honggang Wang, Chonggang Wang, and Ruyan Wang. "A hierarchical packet forwarding mechanism for energy harvesting wireless sensor networks." *IEEE Communications Magazine* 53, no. 8 (2015): 92-98.
- [13] Sharma, Neha, and Kanika Sharma. "Energy Efficient Clustering Based on Expectation Maximization for Homogeneous Wireless Sensor Network." *Energy* 6, no. 8 (2017).
- [14] Aierken, Nueraili, Roberto Gagliardi, Leonardo Mostarda, and Zaib Ullah. "RUHEED-rotated unequal clustering algorithm for wireless sensor networks." In *2015 IEEE 29th International Conference on Advanced Information Networking and Applications Workshops*, pp. 170-174. IEEE, 2015.
- [15] W.B. Heinzelman, A. Chandrakasan, H. Balakrishnan, An application-specific protocol architecture for wireless microsensor networks, *IEEE Trans. Wirel. Commun.* 1 (4) (2002) 660–670.
- [16] <https://www.scalable-networks.com/qualnet-network-simulation> accessed in 21/12/2018.
- [17] D. Wei *et al.*, "An Energy-Efficient Clustering Solution for Wireless Sensor Networks," *IEEE Trans. Wireless Commun.*, vol. 10, no. 11, Sept. 2011, pp. 3973–83.