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ENERGY AWARE DISTRIBUTED CLUSTERING ALGORITHM FOR WIRELESS SENSOR NETWORKS

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Abstract: Clustering is a competent method for increasing network lifetime of wireless sensor networks (WSNs) and also improving its scalability. In a cluster based WSN, energy efficiency and energy awareness are the two key points that must be considered while developing any clustering algorithm. In this paper, we propose an energy aware distributed clustering algorithm (EADCA) that takes care of both the above mentioned issues. The proposed algorithm consists of two phases namely CH selection and cluster formation. In the cluster formation phase we have used TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) which enhances the performance of this algorithm further. The algorithm achieves constant message and linear time complexity.

Keywords: Wireless sensor networks; clustering; energy efficiency; energy awareness; TOPSIS.

1. INTRODUCTION

Wireless sensor networks has become immensely popular among researchers for their potential uses in monitoring environment, surveillance, health care, intruder detection and so on [2]. WSN comprises of spatially distributed autonomous devices using sensors in an unattended given coverage area. The sensor node senses the local information from the target area processes them and sends it to the base station also known as sink. The base station is connected to the internet for transferring the information to the public domain. The main limitation with WSNs is that the sensor nodes have small batteries with limited power sources. There are many such applications where the sensor nodes are dispersed in hostile environment. So, recharging or replacing the node when their energy is exhausted almost becomes impossible. Hence energy consumption has become the very important factor for maximizing the network lifetime of the sensor nodes.

One of the most important techniques for reducing energy consumption is clustering [3]. In cluster based architecture, a number of readily available nodes are branched into specific groups known as cluster with each cluster having a head/leader, often addressed as cluster head (CH). The rest of the member nodes are referred as cluster members. Each member node belongs to only one cluster. The sensed data by members is sent to its respective cluster heads. CH aggregates the raw information and transfers it to the sink in one hop or multiple hops. Clustering has a number of advantages, naming a few are bandwidth conservation, scalability and energy efficiency. In most of the clustering techniques, formation of new clusters is performed periodically for reducing the energy consumption. Selection of CH is a very important factor is clustering. One of the most famous clustering techniques LEACH [4] selects cluster head based on probability. But the major drawback of this technique is that an inefficient node i.e. a node with limited energy might get selected as CH based on probability.

HEED [5] is also a very popular clustering algorithm. In HEED, during cluster head selection residual energy of the sensor nodes is taken as the primary factor and intra-cluster distance as the secondary factor. But an important point taken into account for HEED is, the message overhead produced is very high. Another algorithm was also proposed which used back off [7] strategy. In this algorithm control message overhead was reduced but it did not take care of intra-cluster distance, that might not be reasonable for saving the energy of the sensor nodes. In this paper we propose a new energy aware distributed clustering algorithm for wireless sensor network. In order to be energy aware a sensor node joins a CH on the basis of residual energy. For a node to be energy efficient it joins a CH based on distance to minimize communication energy. Our approach here is to make clustering energy aware as well as energy efficient. The protocol selects CH on the basis of residual energy and also considers intra-cluster distance as second parameter. It uses back-off strategy for CH selection which brings down the message complexity to O (1).

Experimental simulation shows that proposed protocol outperforms the other similar works such as given in [4] and [15]. The remaining paper is arranged as mentioned below- the related work is discussed in section 2. Section 3 presents the energy model. The proposed clustering algorithm EADCA is discussed in section4. The experimental result and conclusion are given in section 5 and section6 respectively.

2. RELATED WORK

Over the years many centralized as well as distributed clustering algorithm have been developed for WSNs [6-12]. Our main focus is on CH selection and formation of clusters, so we have limited our discussion to such technique which mainly focuses of these aspects. We will start our discussion with very famous algorithm LEACH [4] which uses distributed clustering technique. The main drawback of LEACH is that it uses probability as basis for CH selection, so a sensor node having very less energy might get selected as CH. P.Ding et. al., [6] proposed a weight based algorithm (DWEHC) which was very similar to HEED and produced high volume of control message exchange. The authors in [8] proposed GESC (Geographic sensor Clustering Protocol) that used local information of the network for increasing the network lifetime. But this algorithm also produced relatively high control message overhead. The authors proposed [16] power efficient clustering algorithm using honey bet swarm intelligence approach. Although this algorithm is efficient for clustering, it suffers from high message complexity. Cao et. al., [7] proposed DCA which is based on back-off technique. Unlike DWEHC[] and GESC[] its message complexity per node is O(1). However a very important factor like intra-cluster distance was not taken into account which is very important for reducing energy consumption is WSNs. Tarachand et. al., [15] proposed a distributed algorithm based on back off method and the message complexity of the algorithm was given as O(1). CH selection in the algorithm was performed based on residual energy and intra-cluster distance. But in this algorithm, it was assumed that initial energy of every sensor nodes deployed are equal. But in many applications sensor nodes with varying initial energy are deployed for prolonging the network lifetime[13,14]. This algorithm doesn't work very well in the above mentioned scenario and at times nodes with lesser residual energy are also selected as CHs.

3. ENERGY MODEL

In radio model of energy [1] both free space and multi-path fading channels are used which depends on the distance between transmitter and receiver node. If the threshold value d_0 is greater than the distance, then the multi-path (*mp*) model is used else free-space (*fs*) model is considered. Hence the energy consumed by node *i* to transmit *l*-bit message to node *j* over a distance *d* is given by the following equation

$$E_t(l, d) = \begin{cases} l\alpha_{tx} + l\varepsilon_{fs}d^2 & \text{for } d < d_0 \\ l\alpha_{tx} + l\varepsilon_{mp}d^4 & \text{for } d \geq d_0 \end{cases} \tag{1}$$

where, α_{tx} and α_{rx} is the energy consumed to transfer and receive single bit and ε_{fs} and ε_{mp} are amplifying energy required by amplifier in free space and multi-path respectively. The energy dissipated in receiving the *l* bit message by node *j* is given by:

$$E_R(j) = l\,\alpha_{rx} \tag{2}$$

The α_{rx} is dependent on a number of factors namely digital coding, filtering and spreading of signals. Also the energy required by amplifier in free space (ε_{fs}) and multi-path(ε_{mp}) is dependent on the distance between the transmitter and the receiver.

4. PROPOSED ALGORITHM

The proposed algorithm is divided into two phases namely Cluster Head (CH) selection and Cluster formation. Each sensor node takes the decision to declare itself as a Cluster Head (CH) or to join the cluster as a member independently. Hence the proposed algorithm is a distributed algorithm.

A. Cluster Head (CH) Selection

In the first phase, a timer $t(i)$ for node i is initialized and is derived as follows

$$t(i) = \lambda(i) \times T_{CH} \tag{3}$$

$$\lambda(i) = MAV_i - Current.\ Val_i \tag{4}$$

Here, the upper bound for initial energy is denoted as MAV_i(Maximum allowed value) which is fixed as 2J in this case, $Current.Val_i$ is the initial energy of the sensors at the time of deployment and T_{CH} is the maximum time required for Cluster Heads selection. The node whose $t(i)$ expires first is most likely to become CH. The sensor node S_i whose timer expires first declares itself as CH for the next communication round. It broadcasts message containing Current. Val_i identity and its location information within its communication range. On receiving this information node S_j switches off its timer and withdraws itself from CH selection of that communication round. Node S_j records this information into its set $Pot_{CH}(j)$ which is the set of potential CH for the node S_j. To decide its cluster membership Node S_j uses this set, after the CH announcement time is over.

B. Cluster Formation

In this phase whenever node S_j receives only one CH announcement message, then it directly joins the cluster. When node S_j receives CH advertise message from two or more nodes it adds all such node in its potential cluster head set ($Pot_{CH}(j)$). The sensor node then makes the decision on its cluster membership based on two criteria namely residual energy of the CH and the distance between the CH and itself. If one CH is dominant than the other CH in both the criteria, node S_j simply chooses that node as its head. But if there is not any clear winner based on these criteria then TOPSIS method is used in deciding the cluster membership. At first the values of residual energy of CH and distance of S_j from CH are normalised to bring different data sets into a single platform. Vector method of normalization is used for this. Normalised decision matrix is made using

$$r_{ij} = \frac{x_{ij}}{\left(\sum_{i-1}^{m} x_{ij}\right)^{1/2}} \tag{5}$$

where, r_{ij} is normalised value of matrix and m is the number of criteria. The value which we get after normalisation is between 0 and 1. Then a weighed matrix is constructed:

$$V_{ij} = W_j r_{ij}\ i = 1, 2, \ldots, m \tag{6}$$

Here m is number of alternatives and j is number of criteria. The two criteria in this case are residual energy and distance. To remove the partiality factor we have kept values of both weighing factors 0.5 ($W_1 + W_2 = 1$). In the next step both ideal and anti ideal solutions are calculated.

$$V_j^+ = \left\{ \underset{j \leftarrow \text{residual energy}}{\max_i V_{ij}} \ , \ \underset{i \leftarrow \text{distance of CH}}{\min V_{ij}} \right\} \tag{7}$$

$$V_i^- = \left\{ \underset{j \leftarrow \text{residual energy}}{\min V_{ij}} \ , \ \underset{i \leftarrow \text{distance of CH}}{\max V_{ij}} \right\} \tag{8}$$

The separation measure with both ideal and anti-ideal solution is calculated using this formula.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^+)^2} \tag{9}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \tag{10}$$

where, S_i^+ and S_i^- are separation measure for ideal and anti-ideal solution respectively and $i = 1, 2, \ldots, m$. Lastly relative closeness from ideal solution is calculated using

$$C_i = \frac{S_i^-}{S_i^+ + {}_i^-} \tag{11}$$

The value of C_i will range from 0 to 1. The CH whose relative closeness is highest is chosen as CH for node S_j.

C. Complexity Analysis

In our proposed algorithm the control message send by senor node are either for announcement or for joining. Hence the message complexity of our algorithm is given by O(1). Each sensor node individually initiates its timer that can be done in O(1), hence the time complexity of CH selection phase will be O(1). In cluster formation phase, the non-CH uses TOPSIS method for selecting CH. Each step of TOPSIS can be calculated in O(1). In worst case a node can receive n-1 number of CH announcement messages. Therefore the non-CH node will have to calculate relative closeness to the ideal case solution n-1 times in order to decide on the cluster membership. Therefore the total time complexity of the proposed algorithm is given by O (n).

Algorithm: EADCA

```
    /* 1st Phase: Cluster Head Selection */
    for i = 1 to n
        λ(i)=MAV – Current.Val_i
        t(i) = λ(i)×T_CH
    end for
    if (t(i) is expired) then
        broadcast (Cluster head advertisement)
    end if
    if (node j receives CH advertisement message) then
        t(j) is off and update Pot_CH(j)
    end if
    if (t(j) is off and CH advertisement message is received &
            CH announcement time is not over)
        update Pot_CH(j)
    else
        do not update Pot_CH(j)
    end if
/* 2nd Phase Cluster Formation */
for j=1 to n
if(t(j) is off and Pot_CH(j) == 1) then
   Join()/Join the CH
end if
if(t(j) is off and Pot_CH(j) ≥ 2) then
if(i ∈ Pot_CH(j) && Relative Closeness (i) is max to ideal solution)
then
Join()/j → i(CH)
end if
end if
end for
```

Figure 1: Pseudo Code for EADCA.

5. EXPERIMENTAL RESULT

Extensive experiments were performed on the proposed algorithm. The simulation was performed using both MATLAB(R2016b) and C programming language on 64 bit Windows 8 O.S. The parameters used in the simulation along with their values are given in Table 1.

Table 1
Parameters used

Parameters	*Values*
B.S Location	(200, 200)
No. of Nodes	100-200
Communication Range	50m
Initial Energy of sensor nodes	(0.5J – 2J)
MAV	2J
Transmission Energy	50nJ/bit
Amplifier Energy (ε_{fs})	100 pJ/bit/m^2
Amplifier Energy (ε_{mp})	0.0013 pJ/bit/m^4
Data Aggregation Energy	5 nJ/bit
d_0	87.0 m
Control packet size	4000 bits
Message size	200 bits

For the experiment, deployment of nodes was assumed to be done randomly in 400×400 square metre area and the position of the sink was assumed at the co-ordinate (200, 200) ie at the centre of the region. The deployed sensors are heterogeneous in nature ie their initial energy varies from 0.5J to 2J. The proposed algorithm was evaluated based on two performance metrics, namely lifetime of the network and energy consumption. Figure 2 and Figure 3 compares EADCA with BDC Algorithm and LEACH. The result shows our algorithm outperforms the other two algorithms.

On comparing based on various metrics EADCA outperforms many popular existing clustering algorithms. The CHs in our protocol sends data to the base station using one hop which is not a realistic assumption for every scenario. Our future endeavour will be to develop a multi-hop EADCA. We will further check the performance of LEACH and BDC Algorithm in heterogeneous environment.

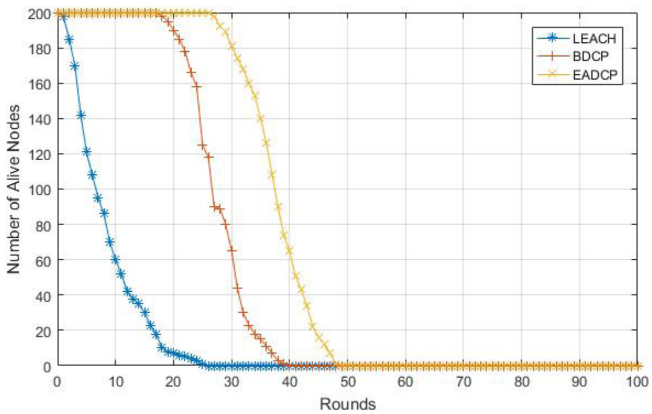

Figure 2: Number of alive sensor nodes per round

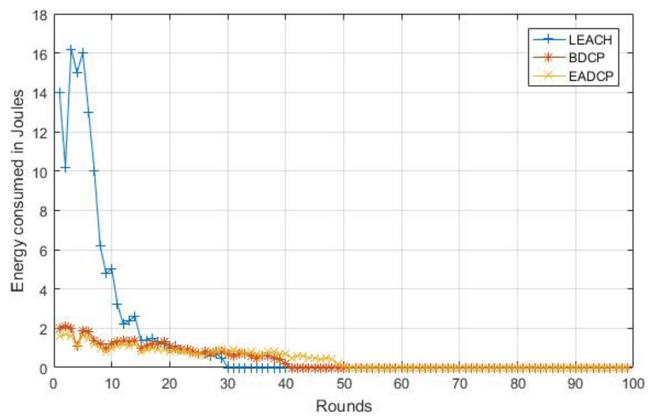

Figure 3: Total energy consumed by sensors nodes in each round

6. CONCLUSION

In this paper we have proposed an algorithm that is energy aware as well as energy efficient. The major advantage of this algorithm is that the control message exchange between senor nodes for CHs selection has been significantly reduced. Our algorithm works well in both the scenarios i.e., for nodes having equal and unequal initial energy. Besides it also takes into account load balancing of CHs in reference with their residual energy. It also minimizes the overall energy consumption of the network by taking into account intra-cluster distance. The message complexity of the algorithm is O(1) and time complexity is O(*n*) for network with n sensor nodes.

References

[1] Heinzelman et. al, "Application specific protocol architecture for wireless microsensor networks", IEEE Transaction on wireless communications, pp. 660-670, 2002.

[2] I.F. Akyildiz, W. Su, Y. Sankarasubramanium and E. Cayirci, "Wireless sensor networks: survey", Computer Network, Vol. 38, pp. 393-422, March 2002.

[3] AA. Abbasi, M. Younis. "A survey on clustering algorithms for wireless sensor networks", Computer Communiaction, pp. 26-41, 2007.

[4] W.B. Heinzelman, A Chandrakasan and H. Balakrishnan, "Energy efficient communication protocol for wireless microsensor networks", In proceeding of Hawaii International conference on System Sciences, Vol. 8, January 2000.

[5] O. Younis and S. Fahmy, "HEED: A hybrid energy-efficient distributed clustering approach for ad-hoc sensor networks", IEEE Transaction on Mobile Computing, Vol. 3, pp. 366-379, November 2004.

[6] P. Ding, J. Holliday and A. Celik, "Distributed energy efficient hierarchical clustering for wireless sensor networks," Lecture Notes in Computer Science, Vol. 3560, pp. 322-339, June-July 2005.

[7] Yangtao Cao and C. He, "A distributed clustering algorithm with an adaptive backoff strategy for wireless sensor networks", IEICE Transaction on Communication. Vol. 89B(2) pp. 609-613, Feb. 2006.

[8] N. Dimokas, D. Katsaros and Y. Manolopoulos, "Energy efficient distributed clustering in wireless sensor networks", Journal of Parallel and Distributed Computing, Vol. 70, pp. 371-383, April 2010.

[9] E. Abdulla, A. Ahmed, N. Hiroki and K. Nei, "Extending the lifetime of wireless sensor networks: a hybrid routing algorithm", Computer Communication, Vol. 35, pp. 1056-1063, May 2012.

[10] S. Lindsay and C. Ragavaendra, "PEGASIS: Power-efficient gathering in sensor information system", In proceeding of IEEE Aerospace Conference, Vol. 3, pp. 1125-1130, March 2002.

[11] A. Majeshwar and D. Agarwal, "TEEN: A routing protocol for enhanced efficiency in wireless sensor networks", In proceeding of International Parallel and Distributed Processing Symposium. pp. 2009-2015, April 2001.

[12] A. Nauman, P. William, R. William and S. Shaymala, "A multi-criterion optimization technnique for energy efficient cluster formation in wireless sensor networks", Information Fusion pp. 202-212, July, 2011. wireless sensor networks", Information Fusion Vol. 12, pp. 202-212, July 20.

[13] V. Gupta, R. Pandey, "An improved energy aware distributed clustering Protocol for heterogeneous wireless sensor networks", Engineering Science and Technology, An International Journal, Vol. 19, pp. 1050-1058, June 2016.

[14] P. Eak-Une, C. Pornavalai "Unequal initial energy assignment for wireless sensor networks" IEEE International Joint Conference on Computer Science and Software Engineering" July 2015.

[15] A. Tarachand, P.K. Jana "BDCP: A backoff-based distributed clustering protocol for wireless sensor networks", IEEE International Conference on Advances in Computing, Communication and Informatics, Oct 2013.

[16] Y. Jiguo, Q. Yingying, W. Guanghui and G. Xin, "A cluster based routing protocol for wireless sensor networks with non-uniform node distribution", International Journal of Electronics and Communication, Vol. 66, pp. 54-61, January 2012.

[17] Z. Liu, Q. Zheng, L. Xue and X. Guan, "A distributed energy-efficient clustering protocol with improved coverage in wireless sensor networks", Future Generation Computer System, Vol. 28, pp. 780-790.

[18] C. Ali and P. Samuel " A distributed energy efficient clustering protocol for wireless sensor networks", Computers and Electrical Engineering Vol. 36, pp. 303-312, March 2012.

[19] M. Bhardwaj and A. Chandrakasan, "Upper bounds on the lifetime of wireless sensor networks", In proceeding of IEEE International Conference on Communications, Vol. 3, pp. 785-790, June 2001.

[20] H. Chan and A. Perrig, "ACE: An emergent algorithm for highly uniform cluster formation," In Proceeding of the First European Workshop on Sensor Networks, pp. 154-171, January 2004.