Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 57 (2015) 807 – 814
Procedia Computer Science

3rd International Conference on Recent Trends in Computing 2015 (ICRTC-2015)

A proposed energy efficient distance based cluster head (DBCH) Algorithm: An Improvement over LEACH

Rohini Sharma[a], Narendra Mishra[a], Dr. Sumit Srivastava[b]

Department of Computer Science and Engineering
Manipal University
Jaipur,303007, India

Abstract

Wireless Sensor Networks are known for their wide range of applications in which no human intervention is required. But the main challenge of Wireless Sensor Networks lies in achieving communications with low energy consumption. In order to overcome the problem of energy consumption, a well-known clustering algorithm, LEACH (Low Energy Adaptive Clustering Hierarchy) was designed. However, LEACH has some disadvantages. In this paper, we propose a new clustering algorithm based on LEACH. It establishes a new Threshold which includes the node energy and distance between node and base station and distance between cluster head and base station for measuring the threshold value. Simulation results show that proposed algorithm is better than LEACH in balancing the node energy and thus enhancing the network lifetime.

Peer-review under responsibility of organizing committee of the 3rd International Conference on Recent Trends in Computing 2015 (ICRTC-2015)

Keywords: ***Wireless Sensor Network; LEACH; Distance between node and base station and distance between cluster head and base station; node energy***

Peer-review under responsibility of organizing committee of the 3rd International Conference on Recent Trends in Computing 2015 (ICRTC-2015)
doi:10.1016/j.procs.2015.07.481

1. Introduction

Wireless Sensor Networks (WSNs) are made of large number of sensors deployed in a certain area. WSNs comprise of sink, sensor nodes and cluster head. WSNs can be used for a variety of environments both for civil as well as military applications. Useful information related to temperature, humidity, etc. can be obtained with the help of Wireless Sensor Networks. They require little or no human interference. There is a layer implementation in Wireless Sensor Networks in terms of application layer, MAC layer, network layer etc. A variety of protocols have been designed for wireless voice and data communication network so far such as TDMA (Time Division Multiple Access), CDMA (Code Division Multiple Access) and contention based protocols like IEEE 802.11. Various attributes such as energy efficiency, scalability, latency, fairness, etc. have to be considered for the design of good protocol. Energy consumption is an asset of TDMA protocol which enables the node to build real communication clusters such as in LEACH. Energy conservation is the core problem & Limitation on energy play a vital role for designing the protocol under implementation. The well-designed protocols can reduce the energy consumption problem and hence increase the network lifetime. Among the given set of algorithm the clustering routing technology is more profound of which LEACH is one of the variant. Low-Energy Adaptive Clustering Hierarchy (LEACH) is a hierarchal routing protocol that uses the mechanism of cluster head rotation. LEACH provides a refined solution for energy consumption. However, conventional LEACH has lot of inadequacies. Based on our findings, conventional LEACH may not be ideal for sensor networks, thus we propose an advanced clustering algorithm. This paper considers the node energy and distance between the cluster head and base station to improve LEACH algorithm.

2. Related Survey

ESCAL [1] is a modified clustering algorithm in which cluster head won't communicate with base station directly. Cluster head will transfer the aggregated data to the nearest node which will further compress and forward the data to the base station. According to this approach, the distance between the cluster head and base station is reduced effectively. Therefore there is reduction in energy dissipation as well.

PEGASIS [2] is an optimal chain based protocol in which each node communicates only with a close neighbor. PEGASIS divides the chain into several chains in order to resolve the problem of delay. This algorithm resolves the problem of delay without the wireless interferences.

LEACH-HEM [3] determines the probability of cluster head based on residual energy. Higher the value of residual energy, greater is the probability of becoming the cluster head. If (r) is the reference energy compared with residual energy of node then,

$$p_i = p_{opt}\left[1 - \frac{\overline{E}(r) - E_i(r)}{\overline{E}(r)}\right] = p_{opt}\frac{E_i(r)}{\overline{E}(r)} \quad (1)$$

Where, p_{opt} the optimal percentage of cluster heads is, $\overline{E}(r)$ is the average energy of the network in round 'r', and threshold for each node is in each round is given as:

$$T_{(S_i)} = \begin{cases} \frac{p_i}{1-p_i\left(r mod \frac{1}{p_i}\right)} & if\ S_i \in G \\ 0 & otherwise \end{cases} \quad (2)$$

p_{opt} is replaced by p_i.

LEACH-M [4] solves the problem for the nodes having the lower energy of becoming the cluster head. This increases the probability of nodes having the higher residual energy to become the cluster head and hence increases the survival time effectively. Under this algorithm, optimum number of cluster heads will be considered and with the help of limiter nodes in each cluster would balance the depleted energy. Threshold is defined as:

$$T_{(n)} = \begin{cases} \frac{p}{1-p\left(r mod \frac{1}{p}\right)} \frac{E_{cur}}{E_{init}} & n \in G \\ 0 & otherwise \end{cases} \quad (3)$$

Where, E_{cur} is the node's current energy and E_{init} is the initial energy. Depending upon the energy consumption node is elected as the cluster head. Node which consumes less energy will be considered as the cluster head.

I-LEACH [5] introduces a new Threshold. It takes residual energy and distance into consideration. Data aggregation tree is constructed to transmit data from cluster head to sink node. Threshold is given as:

$$T_{(n)_{new}} = \begin{cases} \frac{p * k_x}{1-p\left(r mod \frac{1}{p}\right)} & n \in G \\ 0 & otherwise \end{cases} \quad (4)$$

Here $k_x = \frac{E_i}{\bar{E}(r)}$

Where E_i is the residual energy of node i, $\overline{E}(r)$ is average residual energy of all nodes at the current round.

LEACH-R [7] improves the selection of cluster head and proposes a relaying node. The threshold value is defined as:

$$T_r(n) = \begin{cases} \frac{p}{1-p\left(r mod \frac{1}{p}\right)} \left[\delta p + (1-\delta p)\frac{E_{residual}}{E_0}\right] & n \epsilon G \\ 0 & otherwise \end{cases} \quad (5)$$

This threshold ensures nodes with higher value of residual value have a greater chance of becoming the cluster head. δ denotes the number of consecutive rounds during which the node has not been a cluster head. Once the cluster head is selected, R node is selected based on residual node and distance from base station of cluster head as:

$$\lambda = \frac{E_{residual}}{d_{to\ BS}} \quad (6)$$

3. Leach Overview

LEACH (Low Energy Adaptive Clustering Hierarchy) is the most popular hierarchal routing protocol in Wireless Sensor Network. LEACH [6] was first introduced by Heinzelman in 2000.

The defined operation of LEACH can be divided into two phases: Set up phase, in which cluster heads are organized and steady state phase, in which data is transferred to the base station.

The Threshold is set as:

$$\mathrm{T}(n) = \begin{cases} \frac{p}{1-p\left(r mod \frac{i}{p}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (7)$$

However the Election of cluster head depends upon the Threshold value which further depends upon the desired percentage (p), current round r and the set of nodes that have not been cluster heads in the last 1/p rounds symbolized by G.

Set up phase:

A random number is generated between '0' and '1' by each node. This number is then compared with the Threshold value T (n). If this number is less than T (n), node is elected as the cluster head. Node declares itself as a cluster head by sending a broadcast message to the network. Each node figures out which cluster to join according to received signal strength and sends a request message to the adjacent cluster head. Cluster head declares them as the members of clusters on receiving all the messages by nodes.

Steady state phase:

All the members of the clusters send data to the cluster head. Cluster head aggregates the received data and sends this fused data to the base station.

The conventional LEACH has lot of inadequacies. LEACH protocol elects the cluster head randomly. While electing the cluster head it does not consider the energy level of node. Thus if a node having the lower energy is elected as the cluster head, it may fall short of energy and hereafter demise. Thus this node will become invalid. As the number of invalid nodes increase there will be a negative impact on network performance which will shorten the network lifetime.

The other disadvantage of Conventional LEACH is that it does not consider the distance to the base station or distance between cluster head and base station. Thus if a node far away from base station is elected as the cluster head then there will be an increment in the energy consumption which is not a favorable condition for improving the network performance. In order to cover the large surface area the time complexity of the algorithm is computed as O[(N^M)*N]. The proposed algorithm has less time complexity and produces the similar results in comparison to LEACH.

4. Proposed DBCH Algorithm

On analyzing the properties of LEACH, the nodes elected as cluster heads are not an ideal choice for transmitting the data to sink node. In order to solve this problem, new algorithm named Distance Based Cluster Head (DBCH) is proposed for which the threshold value can be calculated as:

$$\mathrm{T}(n) = \frac{p}{1-p\left(r \bmod \frac{i}{p}\right)} + (1-p)\frac{D_{max} - D_{i\ to\ BS}}{D_{max} - D_{min}}\left(\frac{E_R}{E_0}\right) \quad (8)$$

Where, E_R is the residual energy of node for the current round and E_0 is the initial energy. According to this algorithm, cluster head is chosen based on distance of node and base station. The node which is nearer to the base station will be elected as the cluster head. This improvement takes residual energy and distance into account, further it considers the distance from node to cluster head base station and compares the distance from node cluster head & base station. D_{max} and D_{min} represent the maximum and minimum distance from node to base station respectively. In this way, based on residual energy and distance, threshold is calculated.

The transmitting costs (T_{TX}) and receiving costs (R_{RX}) are calculated using the radio model as stated below:

$$E_{TX}(k,d) = (k) + E_{TX-amp}(k,d) \quad (9)$$

$$E_{TX}(k,d) = kE_{elec} + k \in_{friss} d^2 : d < d_{crossover} \quad (10)$$

$$E_{TX}(k,d) = kE_{elec} + k \in_{friss} d^4 : d \geq d_{crossover} \quad (11)$$

For receiving cost:

$$E_{RX}(k) = E_{RX\_-elec}(k) \quad (12)$$
$$E_{RX}(k) = k.E_{elec} \quad (13)$$

Where,
k = length of message in bits
d = distance between the transmitter and receiver node
$d_{crossover}$ = threshold value
$d < d_{crossover}$=free space model
$d \geq d_{crossover}$ =multipath fading

since algorithm suggested minimum multiplication & more comparison to be made as shown in equation '10' due to which the time complexity of the algorithm can be computed as O[(N^M)*N/2], as the number of cluster head remains constant for almost half of the iteration occurred.

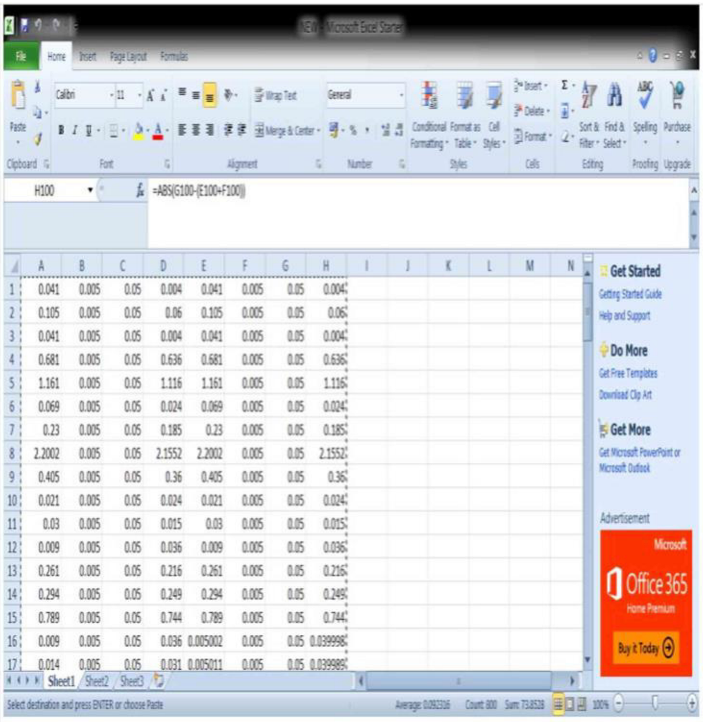
5. Simulation Results and Analysis

For simulation, 100 nodes are placed randomly in a bounding area of 100m x 100m. The initial energy is same for all the nodes.

Table 1

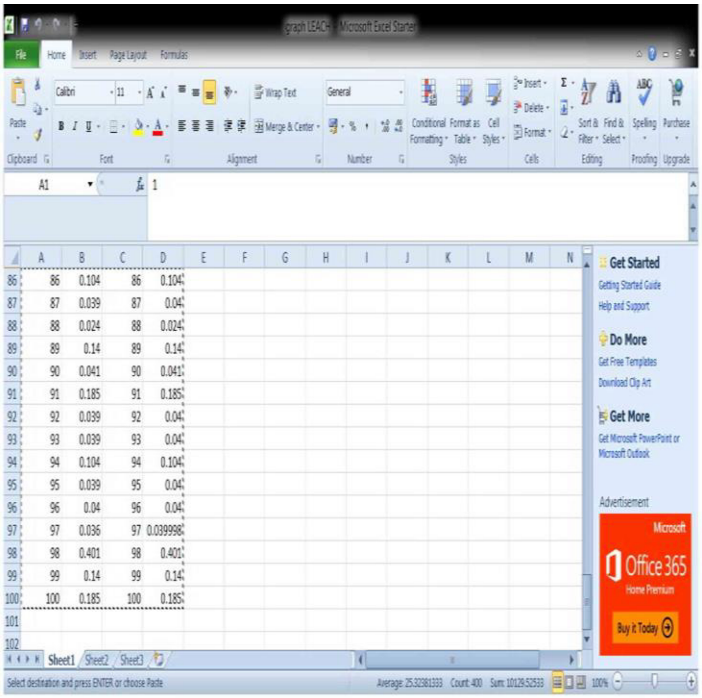
Parameter	Description	Value
E_0	Initial Energy per node	0.05J
$\in_{friss}$	Radio amplifier energy for free space model	10pJ/bit/m^2
$\in_{two\ ray}$	Radio amplifier energy for multi path fading	0.0014pJ/bit/m^2
$d_{crossover}$	Crossover distance for friss and two ray ground attenuation	9.26 m
E_{DA}	Computation energy for beam forming	5nj/bit/signal
E_{elec}	Radio electronics energy	50nj/bit/
K	Data size	100 bit
P	Desired probability of cluster heads	0.01
N	Nodes	100

The simulation was performed using MATLAB as software. The dataset for simulation was defined from the past simulation conducted in the lab. The simulation run for 100 iteration for which the parameters value of LEACH and the Proposed DBCH algorithm has been maintained.



	A	B	C	D	E	F	G	H
1	0.041	0.005	0.05	0.004	0.041	0.005	0.05	0.004
2	0.105	0.005	0.05	0.06	0.105	0.005	0.05	0.06
3	0.041	0.005	0.05	0.004	0.041	0.005	0.05	0.004
4	0.681	0.005	0.05	0.636	0.681	0.005	0.05	0.636
5	1.161	0.005	0.05	1.116	1.161	0.005	0.05	1.116
6	0.069	0.005	0.05	0.024	0.069	0.005	0.05	0.024
7	0.23	0.005	0.05	0.185	0.23	0.005	0.05	0.185
8	2.2002	0.005	0.05	2.1552	2.2002	0.005	0.05	2.1552
9	0.405	0.005	0.05	0.36	0.405	0.005	0.05	0.36
10	0.021	0.005	0.05	0.024	0.021	0.005	0.05	0.024
11	0.03	0.005	0.05	0.015	0.03	0.005	0.05	0.015
12	0.009	0.005	0.05	0.036	0.009	0.005	0.05	0.036
13	0.261	0.005	0.05	0.216	0.261	0.005	0.05	0.216
14	0.294	0.005	0.05	0.249	0.294	0.005	0.05	0.249
15	0.789	0.005	0.05	0.744	0.789	0.005	0.05	0.744
16	0.009	0.005	0.05	0.036	0.005002	0.005	0.05	0.039998
17	0.014	0.005	0.05	0.031	0.005011	0.005	0.05	0.039989

Table 2: Data set for simulation



	A	B	C	D
86	86	0.104	86	0.104
87	87	0.039	87	0.04
88	88	0.024	88	0.024
89	89	0.14	89	0.14
90	90	0.041	90	0.041
91	91	0.185	91	0.185
92	92	0.039	92	0.04
93	93	0.039	93	0.04
94	94	0.104	94	0.104
95	95	0.039	95	0.04
96	96	0.04	96	0.04
97	97	0.036	97	0.039998
98	98	0.401	98	0.401
99	99	0.14	99	0.14
100	100	0.185	100	0.185

Table 3: the proposed residual output

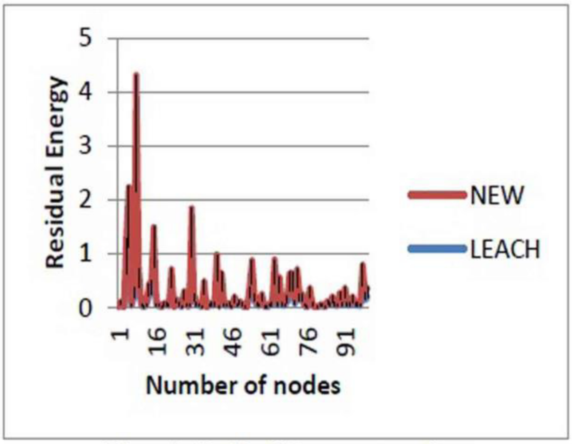


Figure 1: Residual Energy comparison.

The simulation suggested that during the initially time from say up-to '20' iteration there is a random change in the threshold value, the cluster head & the number of dead nodes, but it moves towards the constant or fixed values once the number of iteration increases and less values remains to be compared. Also the figure 1 suggested that almost the lesser time has been taken by the proposed method in comparison to the LEACH algorithm.

6. Conclusion

Clustering algorithm is an approach to enhance the network lifetime. Based on shortcomings of original LEACH, this paper proposed a modification to original LEACH algorithm using the distance measure with the current node. It does so by introducing a new Threshold from node energy and distance factors of individual node. The simulation result shows that the new algorithm has a better performance compared to original LEACH.

7. Future Work

The figure 1 suggested that further study of parameters in simulation software like NS2 or Matlab, specific parameters as featured variable of importance can be chosen for study. This will optimize the given dataset results to larger extent. . The next focus is a combination of the improved algorithm and multi-hop routing, and paying more attention to the complexity of the algorithm and network overhead.

8. References

[1] Jing Chao, Gu Tianlong, Chang Liang "ESCAL: An Energy-Saving Clustering Algorithm Based on LEACH", IEEE, 2008.

[2] Min Hong, Yi Sangho, Heo Junyoung, Cho Yookun, Hong Jiman "Energy-Efficient Data Aggregation Protocol for Loaction- Aware Wireless Sensor Network", 2008 International Symposium on Parallel and Distributed Processing with Applications, IEEE, 2008.

[3] Chen Guijun, Zhang Xueying, Wang Maofeng "An improved LEACH algorithm based on heterogeneous energy of nodes in Wireless Sensor Nodes", 2012 International Conference on Computing Measurement, Control and Sensor Network, IEEE, 2012.

[4] Long-Long Xu, Jun-Jian Zhang "Improved LEACH Cluster Head Multi-hops Algorithm in Wireless Sensor Networks", 2010 Ninth International Symposium on Distributed Computing and Applications to Business, Engineering and Science, IEEE, 2010.

[5] [Jing Yang, Zetao Li, Yi Lin "An improved Routing Algorithm based on LEACH for Wireless Sensor Networks", IEEE, 2013.

[6] Heinzelman Rabiner Wendi, Chandrakasan Anantha, Balkrishnan Hari "Energy- Efficient Communication Protocol for Wireless Micro sensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences-2000, IEEE, 2000.

[7] WANG Ningbo, ZHU Hao "An Energy Efficient Algorithm Based on LEACH Protocol" 2012 International Conference on Computer Science and Electronics Engineering, IEEE, 2012.