Journal of Solar Energy Research (JSER)

Journal homepage: www.jser.ut.ac.ir

Minimising wireless sensors' energy consumption for net zero energy building

P.Khodabakhsh[a*], M.Khademi[b], M.Moadel[c]

[a] *Department of Computer Engineering, Islamic Azad University South Tehran Branch,Tehran, Iran; [*]Email: st_p_khodabakhsh@azad.ac.ir*

[b] *Department of Applied Mathematics, Islamic Azad University South Tehran Branch,Tehran, Iran*

[c] *Department of Energy Engineering, Islamic Azad University, Science and Research Branch, Tehran, Iran*

ARTICLE INFO

Received: 09 Nov 2017
Received in revised form: 29 Nov 2017
Accepted: 02 Dec 2013
Available online: 05 Dec 2017

Keywords:
Net Zero Energy Building (NZEB), LEACH protocol, Internet of Things (IOT), Genetic Algorithm, Fuzzy clustering;

ABSTRACT

Wireless sensors networks consist of several tiny battery powered devices which are utilized to monitor and gather information of desired area, such as a Net Zero Energy Building. As there is no way to recharge the nodes' energy and batteries, efficient energy consumption plays crucial role in prolonging nodes' and network's lifetime. One of the most popular routing protocol is LEACH protocol, which suffers from drawbacks, despite several modifications have been deployed. This research aims to optimize the Leach protocol from three different aspects. Initially, the allocated energy of network is distributed to each nodes based on their distance with base station. The more distance between a node and BS, the more energy portion is allocated to the given node. Secondly, Genetic algorithm has been employed to select optimal cluster head set whose fitness function addresses number of CHs and distance between CHs and the BS. Lastly, sensor nodes are clustered by fuzzy clustering. Comparing the results with previous versions illustrates that the proposed modifications could prolong considering network and improve the energy consumption and the modified LEACH achieves 10% improvement in terms of survival rate of nodes.

1. Introduction

The Net Zero Energy Building (NZEB) has been introduced to address to instructing building which significantly decrease energy demands and costs and emit zero greenhouse gas (GHG) [1]. According to information supplied by [1], the NZEB has attained the global market's attraction in the last few years. In general, there are two strategies to design ZEBs, (i) minimizing the need for energy use in building by more energy-efficient measures and (ii) employing renewable energy and other techniques to satisfy the needs for energy. Initially, Buildings are expected to be energy efficient and meet the energy standards. The energy efficient measures which impact the energy consumption can be divided into three categories, including building (a) envelope, which aims to decrease the summer heat and energy loss in winter, (b) Internal conditions, the internal heat sources and the maximum allowable temperature of building's indoor are the factors which play crucial role in air conditioning of the buildings and (c) Building services systems, namely HVAC (heating, ventilation and air conditioning) and electrical services (including lighting) which are considered as the main consuming energy component in the buildings. Meanwhile, ZEBs can be built by employing energies and other technologies, including PV (Photovoltaic), Wind turbines and etc. [2].

This study aims to focus on optimizing energy consumption in buildings by employing computer-aided techniques, the Internet of Things (IOT), which refers to one of the dominant technologies based on interconnected devices by a common network [3]. IoT in a NZEB provides smart objects distributed throughout networks to sense a desired event, collect and transmit information such as lighting, indoor air quality or the other energy parameters, to the nearest cluster heads(CHs) [4-6]. These smart objects called sensors have limited energy, so applications and protocols for IoT should be carefully designed for optimized consumption of energy in order to prolonging the network lifetime [7]. Employing IoT techniques can be aided to manage and control the energy consumption and maximize energy efficiency to attain NZEB.

One of the most effective methods to increase the performance of IoT is low-energy adaptive clustering hierarchy (LEACH) [8]. It is considered as one of the most popular energy-based protocol which aims to reduce the network's energy consumption by randomizing the process of CH selection. Despite LEACH has been assumed as an efficient energy saving protocol, it suffers from several problems, namely random election of cluster heads or lack of priority among sensor for cluster heads selection [9]. Hence, various improvements have been proposed to improve the energy consumption and cluster heads selection.

G. Smaragdakis and et al. in 2004 proposed Stable Election Protocol (SEP) approach which is an extension of LEACH to use in WSN. This protocol has the same function as LEACH, but the difference is that SEP nodes have two different levels of energy and the chances of higher energy nodes to be selected as CH exceed the chances of the other nodes [10]. In 2013, a modified Genetic algorithm (GA) based on evolutionary approach was suggested by Pratyay Kuila et al for load balancing so as to reduce the energy consumption in WSN [11].

This was followed by proposing an improved Binary Particle Swarm Optimization (BPSO) algorithm with modified connected dominating set that utilizes residual energy for discovery of optimal number of clusters and cluster head [12]. Although this method improves the number of clusters, the number of nodes alive and remaining average energy is reduced to zero beyond 800 rounds. In 2015, Rohini Sharma and et al. introduced 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 [13].

Following sections give a brief introduction of LEACH, genetic algorithm and fuzzy clustering and a detailed explanation of proposed strategy. Afterwards, section 2 and 3 provide the conclusion of this study and highlight some future works.

2. Materials and Methods

2.1. Low Energy Adaptive Clustering Hierarchy (LEACH)

The operation of LEACH is done in several rounds which are divided into two steps: Setup and transferring step. Initially, a random number in the interval of [0,1] is generated and allocated to each node of the network. If the number was less than the threshold, the node would be a CH. The threshold value is calculated by equation (1):

$$T(n) = \begin{cases} \dfrac{P}{1 - p\left(r \bmod \dfrac{1}{p}\right)} & c_i(t) = 1 \\ 0 & c_i(t) = 0 \end{cases} \quad (1)$$

Afterwards, in the second step, once the CHs have been selected and clusters have been formed, the member nodes sent their collected data to the CHs. This is followed by data transferring between CHs and Base Station (BS) (Figure 1).

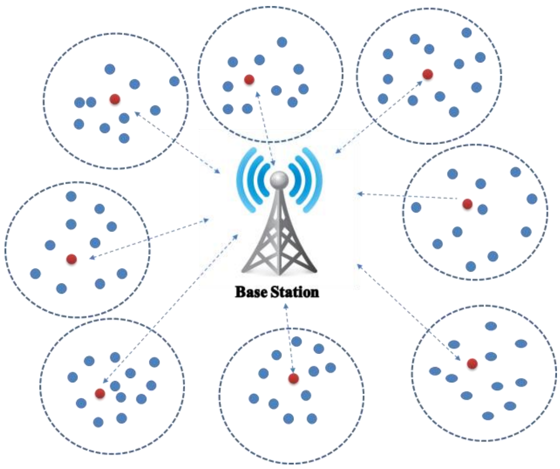

Figure 1. Data transferring in Leach protocol

As Figure 1 indicates, the only way for data transformation is done by CHs which is illustrated by red points in each clusters.

In the proposed method, to improve the CH selection and member nodes clustering, genetic algorithm and fuzzy clustering were used, respectively. In other words, genetic algorithm generates an optimal set of CHs which is an input of fuzzy clustering. The Figure 2 shows how to improve LEACH and is divided into three sections; Initialization, CHs Selection and Clustering, which are explained in following sections.

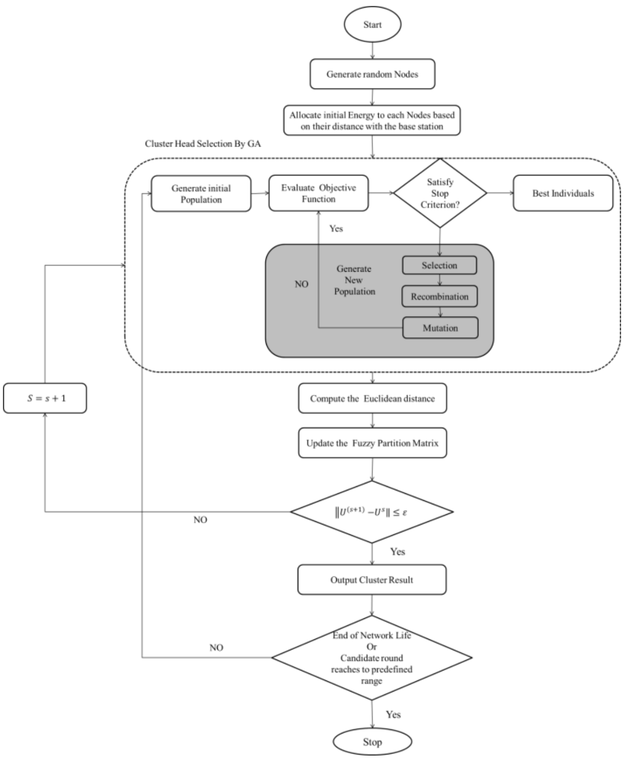

Figure 2. The proposed method flowchart

2.2 Genetic Algorithm

As mentioned before, binary genetic algorithm was utilized for the purpose of selecting an optimal set of CHs which plays a crucial role in optimization energy consumption in wireless networks. As following example in Figure 3 shows, a "1" means the node considered as a CH; otherwise it is a normal node:

N_1	N_2	N_3	…	N_n
0	1	1	…	0

Figure 3. An example of Genetic Algorithm output.

It is obvious that N_2 and N_3 are CH and the remaining nodes are the normal nodes.

Genetics algorithm [14] consists of three main operators, population generator, crossover and mutation. Having randomly generated a population of candidate solutions, a fitness function is calculated for each individual. Next, mutation and crossover operators are applied on the population.

In the crossover step, two parents are selected to create their offspring. Additionally, the mutation is performed to changes a bit with value of "1" to "0" and vice versa. This process operates in several rounds to reach an optimal solution which indicates optimal set of CHs.

2.3 Fuzzy Clustering

In the last part of the process, nodes are clustered using fuzzy clustering. When applying of genetic algorithm was completed, the nodes chosen as CHs were fed through to fuzzy clustering phase as center nodes and clustering process was carried out based on number of cluster heads.

Once cluster heads have been determined by GA, a coefficient was assigned to each point implying the membership degree to each cluster, which computed by equation (2):

$$u_{ik} = \frac{\|p_i - x_k\|^{\frac{-2}{m-1}}}{\sum_{j=1}^{n}\|p_j - x_k\|^{\frac{-2}{m-1}}} \quad i = 1,2,\dots,c \ ; k = 1,2,\dots,n, \sum_{i=1}^{c} u_{ik} = 1 \tag{2}$$

Where p_i and x_k refers to cluster heads and member nodes, respectively and to control the fuzzy degree of the membership matrices, U, a parameter, m was used which is usually set equal to 2. The value of U was randomly determined at the beginning of the clustering, but during the next iterations, the matrices were updated iteratively to achieve the minimal value for objective function which is achieved by equation (3):

$$F_{obj} = arg_C \min \sum_{i=1}^{n}\sum_{j=1}^{c} u_{ij}^{m}\|x_i - c_j\|^2 \tag{3}$$

Fuzzy clustering aims to minimize its objective function, where x_i and c_j are sensor nodes and CHs, respectively.

3. Results & Discussion

This paper improves the cluster selection process and network's member nodes clustering by GA and fuzzy c-mean clustering, respectively. In order to protocol simulation, MatLab has been used which distributed 90 sensor nodes in the plane region of 300×300. The initial energy of each sensor is set based on their distance with the BS, the more distance between sensor nodes and BS, the more energy is allocated to the sensor.
The value of initial parameters used in the LEACH and GA, are summarized in Table 1 and Table 2:

Table 1. The value of GA parameter

Parameters	Values
Population	100
Length of chromosomes	90
Max Iteration	150
Proportion of Mutation	5%
Proportion of Crossover	95%

Table 2. The parameters of Leach protocol.

Parameters	Values
Number of Sensors	90
The initial node energy	0.5
Energy consumed by the amplifier to transmit at a short distance	10pJ/bit
Energy consumed by the amplifier to transmit at a longer distance	0.0013pJ/bit
Energy consumed in the electronics circuit to transmit or receive the signal	50pJ/bit
Data packet	4000 bits
Control packet	100 bits
Data aggregation energy	5pJ/bit/report
The Sensing area	300×300

GA's fitness function has significant role in improvement of LEACH's performance, given that this function has to score the CH sets based on the network's energy consumption factor, namely distance between BS and CHs, and balances among them. Therefore, it not only affected on the CHs selection and its output but also played a crucial role in clustering,
As CHs consume more energy than normal nodes, then the high number of CHs leads to consume more energy and lessens the network life span. Meanwhile, distance between BS and sensors has crucial influence on network's energy consumption as well. If the distance between BS and CHs increases consuming energy to send their packets will be risen and consequently the life span of network will be reduced. On the other hand, the CHs must cover the entire region to access their member nodes. These results to compute the fitness function as equation 4:

$$F(n) = w^2 \times \frac{distance\ between\ CH\ \&\ BS}{Total\ Distance} + (1-w)^2 \times \frac{Number\ of\ CH}{Total\ number\ of\ sensors} \quad (4)$$

The equation 4 not only avoids increasing number of CHs but also helped to reduce between BS and CHs in the region. Additionally, we used the power of 2 to avoid negative values in the equation.
In this research, the network lifetime has been measured in order to analysis the result of the improved system This time can be divided into three sections: First Node Death (FND), Half Node Death (HNF) and All Nodes Death (AND). The first Node death and half node death refer to the rounds in which the first node and the half of nodes died because of finishing their energy.

Table 3. Parameters of different versions of LEACH

	FND	HND	AND
Simple Leach	941	1218	3000
Fuzzy Leach	859	1374	3189
GA-LEACH	845	1356	3241
Fuzzy- GA- Leach	754	1127	3524

According to the results that illustrate in figure 4 in which AND, FND and HND and are indicated by, red, yellow and orange bars, respectively, the improved LEACH could exceed its normal version. Although the proposed method reached to least

HND, its AND parameter rose at around 3500. By result, the proposed scheme could extend the lifetime of the network and achieve 10% improvement in terms of survival rate of nodes comparing to original version of LEACH Protocol.

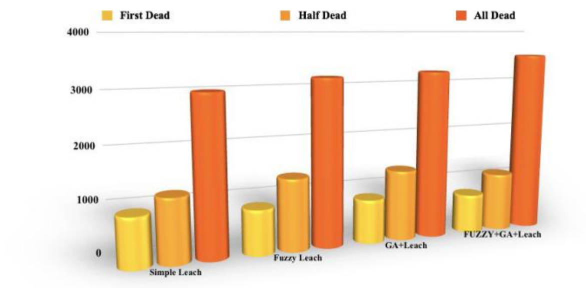

Figure 4. Comparison of Results of different version of LEACH

4. Conclusion and Future work

The objective of this research was to extend the network's lifetime by employing IoT technique which leads to achieve nearly zero energy in buildings. In this study, one of the well-known protocols were employed and improved by optimization and clustering algorithm. As mentioned before, GA has employed for selecting cluster heads. Distribution of cluster heads, distance with BS, and the number of Cluster heads were the measures which were under Consideration. On the other hand, fuzzy clustering was employed to improve clustering phase. From information provided, it is evident that the improved protocol considerably prolongs the network lifelong and reduces the energy consumption. Integrating above technology and ZEB design strategies not only maximizes energy efficiency, but also decreases the dependency to municipal supplies.

In this research, in cluster heads selection phase, multiple criteria were involved which were combined into a single composite function. Our suggestion for future work is to employing multi-objective optimization algorithms. This causes several conflicting objectives to be optimized simultaneously.

References

[1] L. Wells, B. Rismanchi and L. Aye, "A review of Net Zero Energy Buildings with reflections on the Australian context.," *Energy and Buildings* , 2017.

[2] D. H. Li, L. Yang and J. C. Lam, "Zero energy buildings and sustainable development implications--A review," *Energy*, vol. 54, pp. 1--10, 2013.

[3] A. Rafaelli, D. Altman, D. Gremler, D. Grewal, B. Iyer, A. Parasuraman and K. de Ruyter, "Invited Commentaries on the Future of Frontline Research," *Journal of Service Research*, vol. 20, no. 1, pp. 91--99, 2017.

[4] F. AlFaris, A. Juaidi and F. Manzano-Agugliaro, "Intelligent homes' technologies to optimize the energy performance for the net zero energy home," *Energy and Buildings*, vol. 153, pp. 262--274, 2017.

[5] K. R. Babu and C. Vyjayanthi, "Implementation of net zero energy building (NZEB) prototype with renewable energy integration," in *IEEE Region 10 Symposium (TENSYMP), 2017*, IEEE, 2017, pp. 1--5.

[6] F. Shrouf and G. Miragliotta, "Energy management based on Internet of Things: practices and framework for adoption in production management," *Journal of Cleaner Production*, vol. 100, pp. 235-246, 2017.

[7] Sudhanshu Tyagi , Neeraj Kumar, "A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks," *Journal of Network and Computer Applications*, 2013.

[8] A. Al-Baz and A. El-Sayed, "A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks," *International Journal of Communication Systems*, 2017.

[9] J. Xu, N. Jin, X. Lou, T. Peng, Q. Zhou and Y. Chen, "Improvement of LEACH protocol for WSN," in *Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on*, 2012.

[10] G. Smaragdakis, I. Matta and A. Bestavros, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks," in *Boston University Computer Science Department*, 2004.

[11] P. Kuila, S. K. Gupta and P. K. Jana, "A novel evolutionary approach for load balanced clustering problem for wireless sensor networks," *Swarm and Evolutionary Computation*, vol. 12, pp. 48--56, 2013.

[12] S. Thilagavathi and B. Gnanasambandan Geetha, "Energy aware swarm optimization with intercluster search for wireless sensor network," *The Scientific World Journal*, vol. 2015, 20115.

[13] Rohini Sharmaa, Narendra Mishraa, Dr. Sumit Srivastavab, "A proposed energy efficient distance based cluster head (DBCH) Algorithm: An Improvement over LEACH," *Procedia Computer Science*, 2015.

[14] S. K. Jha and E. M. Eyong, "An energy optimization in wireless sensor networks by using genetic algorithm," *Telecommunication Systems*, pp. 1--9, 2017.