ICAI 2023
12th International Conference on Applied Informatics
Eger, Hungary, 2023

Effect of the Modulation on the Cluster Head Election in Cost Balanced LEACH*

Amine Korteby[a], Djamila Talbi[b], Gal Zoltan[c]

[a]University of Debrecen, Faculty of Informatics
korteby.amine@inf.unideb.hu

[b]University of Debrecen, Faculty of Informatics
talbi.djamila@inf.unideb.hu

[c]University of Debrecen, Faculty of Informatics
gal.zoltan@inf.unideb.hu

Abstract

Wireless Sensor Networks (WSNs) have made significant progress in recent years due to advancements in hardware and reduced costs. Based on the application and network architecture, several protocols have been created. One of the most energy-efficient solutions in WSN environments is the LEACH (Low Energy Adaptive Clustering Hierarchy) mechanism. Using the cluster head feature of the nodes, this hierarchical protocol aggregates and forwards data from cluster members to a fixed sink node. By introducing motion capability to the sink node and balancing the cluster head election decision based on the distances between the nodes and the remaining energy of the potential cluster head candidates, we propose a new family of routing mechanisms called Cost Balanced LEACH (CB-LEACH). In this research work, we modulate the balance factor α conform to different rules and we analyzed the behavior of the system and its most important features.

The Low-Energy Adaptive Clustering Hierarchy WSN routing protocol is well-known in research studies. This energy-efficient hierarchical mechanism is based on clusters formed during the system's epoch time [2]. It increases network lifetime by randomly selecting Cluster Heads (CH). Members of the cluster send data to the

*This work has been supported by QoS-HPC-IoT Laboratory and project TKP2021-NKTA of the University of Debrecen, Hungary. Project no. TKP2021-NKTA-34 has been implemented with support provided by the National Research, Development, and Innovation Fund of Hungary, financed under the TKP2021-NKTA funding scheme.

CH, which forwards it to the WSN's gateway, known as the Sink Node (SN). The energy consumption of the sensor nodes is reduced as a result of this intermediary distribution step [4][5]. LEACH is the most effective energy optimizer mechanism for WSN. However, when the potential of CH election is based solely on node energy level, arbitrarily defined cluster formation occurs, resulting in unequal cluster distribution in the network [1][3].
In our work, the rule of the CH election in each of the epoch periods is based on the formula:

$$\mathrm{COST}(i,j,\alpha) = \alpha \cdot \frac{E_0}{E_{PCH_j}} + (1-\alpha) \cdot \left(\frac{D(i,j)}{d_0}\right)^{2b} \tag{1}$$

where balance factor α is modulated conform to different rules discussed later. When $\alpha = 0$, the energy level does not affect the Potential Cluster Head (PCH). When $\alpha = 1$, the distance has no effect between the node and PCH. We let the balance factor to gate values in the limited interval: $0 \leq \alpha \leq 1$. To modulate the balance factor in each epoch period we consider four metrics conform to the following way:

$$\alpha = \alpha(\mu(E), \sigma(E), \mu(D), \sigma(D)) \tag{2}$$

where $\mu(E)$, $\sigma(E)$, $\mu(D)$, $\sigma(D)$ are the mean and standard deviation of the alive nodes' energy and distance between pairs of alive nodes of the WSN, respectively. There were used four modulation rules of the factor α.
Case 1: α is a product of media over max ratios of the distance and energy.

$$0 < \alpha_1 = \frac{\mu(E)}{\max(E)} \cdot \frac{\mu(D)}{\max(D)} \leq 1 \tag{3}$$

Case 2: α is a product of media over max ratios of the distance and energy to power 0.5.

$$0 < \alpha_2 = \left(\frac{\mu(E)}{\max(E)} \cdot \frac{\mu(D)}{\max(D)}\right)^{1/2} \leq 1 \tag{4}$$

Case 3: α is 1 - a product of media over max ratios of the distance and energy to power 0.5, called actor β.

$$0 < \alpha_3 = 1 - \beta \leq 1 \tag{5}$$

$$\beta = 1 - \left(\frac{\mu(E)}{\max(E)} \cdot \frac{\mu(D)}{\max(D)}\right)^{1/2} \tag{6}$$

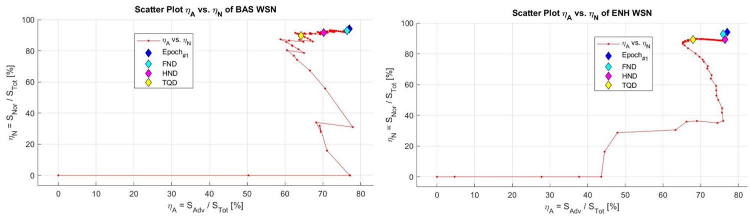
Case 4: α is the conditional ratio of the distance and energy (Coefficient of Variations.

$$CV(E) = \frac{\sigma(E)}{\mu(E)} > 0 \tag{7}$$

$$CV(D) = \frac{\sigma(D)}{\mu(D)} > 0 \tag{8}$$

$$\alpha_4 = \frac{\min\{CV(E), CV(D)\}}{\max\{CV(E), CV(D)\}} = \begin{cases} \frac{CV(E)}{CV(D)}, \text{ if } CV(E) < CV(D) \\ \left[\frac{CV(E)}{CV(D)}\right]^{-1}, \text{ if } CV(D) \le CV(E) \end{cases} \tag{9}$$

It was found that when α=1-β, where β is a product of media over max ratios of the distance and energy to power 0.5, our routing mechanism outperforms the other modulation cases in all the features that the system offers.



(a) Scatter plot η_A vs. η_N of BAS-LEACH (v =10 m/s).

(b) Scatter plot η_A vs. η_N of ENH-LEACH (v =10 m/s).

Figure 1. Scatter plot of η_A vs. η_N.

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