Clustering in Wireless Sensor Networks using IDEC-LEACH-C Hybrid Energy Efficient Protocol

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ABSTRACT
Recent advances in wireless telecommunication and electronics have provided the ability to design and produce sensors with low consumption power, small size, fair price and different usages. These small sensors, which are able to accomplish tasks like receiving different peripheral information, are the cause of creation of an idea for developing networks called Wireless Sensor Networks (WSN). The most challenging task in WSN networks is routing. There are different protocols in WSN, which were used for routing data packages from beginning to destination. LEACH is the first and the most famous hierarchical clustering algorithm with effective energy for WSNs, which was proposed for decreasing the energy consumption. Definite clustering protocol (DEC) uses the remaining energy of each cluster node (RE) for the process of selecting CH. As long as the RE of each node is higher than its adjacent, DEC considers that node as a selection choice and guarantees that each CH has enough energy to cope with its role, of course until the end of the network lifetime (unlike LEACH). In this research, it is decided that in order for improving the results, the LEACH-C protocol, which excels the performance of the LEACH protocol, to be combined with the protocol IDEC (Improved DEC). In this study, the descriptive-analytical approach was carried out as a research methodology based on the proposed model. The proposed model was combined with two algorithms of LEACH-C and IDEC. In this study, results of LEACH, LEACH-C and DEC were compared. According to the research results, we observed that the performance of the proposed protocol excels other proposed protocols. The protocol ICED & LEACH-C saves energy. As we know, decreased energy consumption increases lifetime of the network.

General Terms
Wireless Sensor Networks (WSN); Energy

Keywords
Low Energy Adaptive Clustering Hierarchy (LEACH); Low Energy Adaptive Clustering Hierarchy-Centralized (LEACH-C); Definite Clustering Protocol (DEC)

1. INTRODUCTION
Sensor nodes usually acquire their power from limited-life batteries and most often, the battery is not rechargeable. The energy problem in WSNs is one of the main impediments for restricting complete utilization of this technology. [28] The key challenge of routing a wireless sensor network (WSN) is dealing with the issue of energy efficiency and extending the network lifetime. By categorizing sensor nodes, the hierarchical connection among them can be more scalable, more energy-efficient, with less influence, and can have a better lifetime, compared to the flat connections. [16] The difference between ordinary wireless networks and wireless receiver networks is that the sensors are sensitive about energy consumption. Decreasing the energy consumption is of utmost importance in designing wireless sensor networks. [25] The purpose of this study is to decrease energy consumption and increase network lifetime.

LEACH is the first and the most famous hierarchical clustering algorithm, which decreases the amount of consumed energy. This protocol uses the unstable protocol (CSMA MAC) as the signal message that includes CHID, CM-ID and request header. The clustering process was carried out in two steps: establishment and ready made. Cluster heads are distributed unequally, which leads to decreasing the number of nodes alive and wasting more energy that finally decreases the network lifetime. In this protocol, the optimum number of cluster heads for 100 nodes is 5. There is no overload for BS in making decision about clustering. LEACH is appropriate when the local coordination of nodes in clustering occurs without interference of BS. [2]

LEACH was based on aggregation (or combination) technique that combines main data with smaller data that only transmits meaningful data to single sensors. LEACH uses the CH position random rotation with high energy rather than static method to give this opportunity to all sensors to act as CH and prevent from battery depletion of a single sensor and consequently its withdrawal [1].

LEACH-C is the improved form of LEACH protocol, which equally distributes cluster heads in the network and this leads to decreased waste of energy and increased network lifetime. The optimum number of cluster heads for 100 nodes, is 3 - 5. It is suitable for centralized and definite methods of clustering. However, the weakness of LEACH-C is causing the overload in BS, too much involvement in each step and aspect of the clustering process. [2]

The following conclusion can be drawn between LEACH and LEACH-C (centralized):

Advantages of LEACH over LEACH-C: LEACH is a distributed, random and probabilistic algorithm, which imposes no overload on BS in decision making for clustering. This protocol has increased the network lifetime more than LEACH-C. Only when the network is formed in a consistent distribution of clustering and doesn't have any anticipation about the number of expected cluster heads regarding the network parameters like remainder energy of each sensor node in network and decision making about clustering etc. [2]

Advantages of LEACH-C over LEACH: LEACH- C can be chosen when centralized and definite methods are needed for clustering. In addition, LEACH-C covers the whole network regarding the remaining energy of each node in the network, before making the decision for clustering. This can create a

more uniform distribution than LEACH clustering. However, the weakness of LEACH-C, which has led to increased overload in BS, is too much involvement in each stage and each aspect of the clustering process. [2]

It can be concluded from these results that LEACH may be preferred, if the local coordination of nodes in clustering occurs without interference of BS; and LEACH-C may be chosen when centralized and definite methods cover the whole network and it is expected that the lifetime and number of optimum clusters be increased. [2]

Definite clustering protocol (DEC) uses the remaining energy (RE) of each cluster node for the CH selection process. Selecting CH occurs locally and based on RE of each node, and against LEACH, each round will be independent of the next round. When RE of each node is higher than its adjacent, DEC considers that node as a selected candidate and guarantees that each CH has enough energy to cope with its role, at least until the end of network lifetime (against LEACH). [1]

This protocol is definite, unlike LEACH that is probabilistic, which is more powerful and more stable than probabilistic models. The selection of cluster head may be carried out using the remainder energy in each node. Request message includes CHID, CM- ID, CM-RE and request header. This protocol guarantees that each cluster head has enough energy to perform its role. The clustering process was accomplished in two steps of the establishment and ready mode (like LEACH protocol). Simulation results indicate that DEC outperforms LEACH in a waste of energy, which leads to increased network lifetime. [1]

Finally, we conclude that LEACH-C protocol outperforms LEACH and in this article, we combine this protocol with DEC protocol to attain better results, i.e. decrease the energy consumption using this combination, and this measure shows innovativeness of the present research.

The rest of the paper was organized as follows: section 2 reviews previous works, section 3 provides the research methodology, which includes the research model that introduces the combined protocol and research methodology, section 4 presents research results, in which the results of the suggested combined protocol is compared to other protocols. Finally, section 5 concludes the research, provides its strengths and weaknesses and highlights the trends for future research.

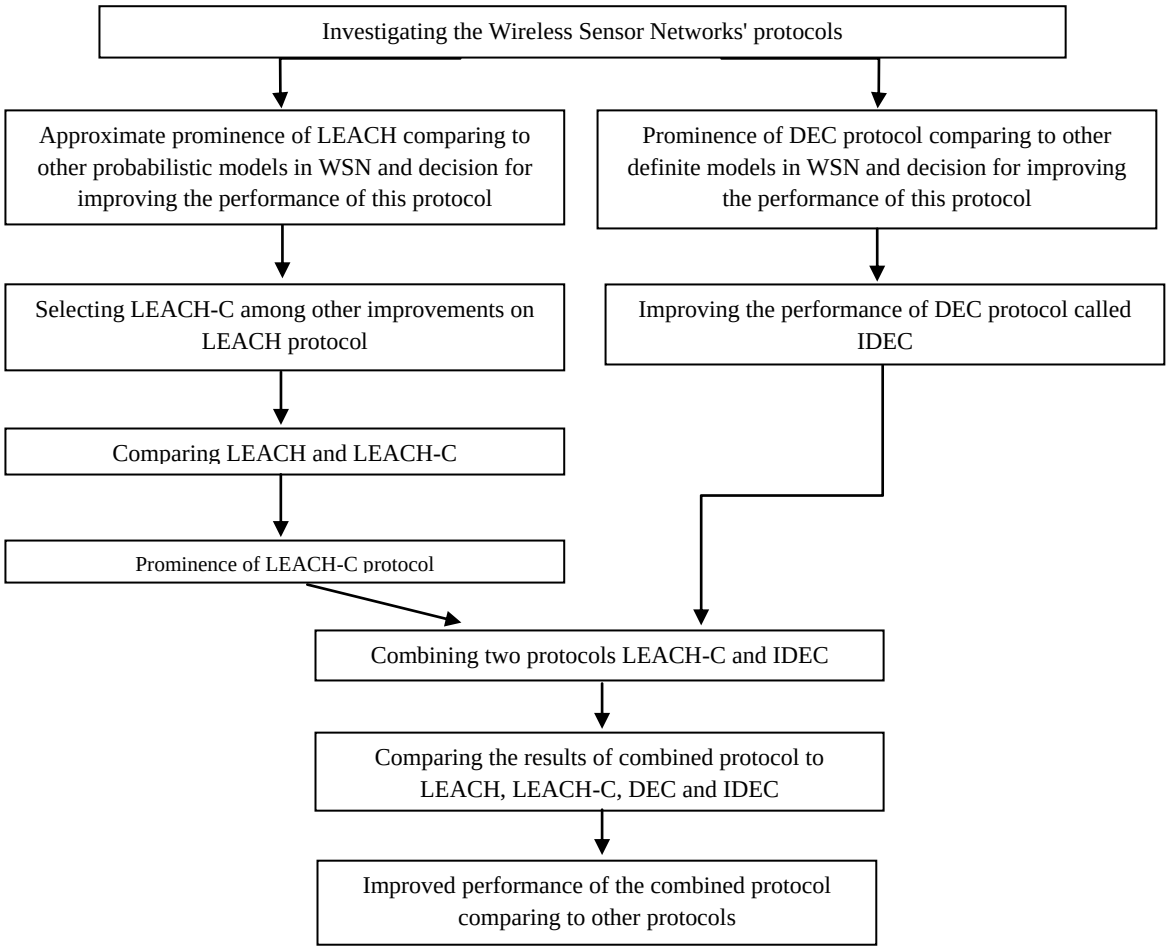
2. LITERATURE REVIEW

Comparative investigation of clustering based on routing techniques for WSN is provided by [28], who investigates the available routing based on hierarchical clustering with effective energy for wireless sensor networks. Clustering features are provided by [13], who fully investigated hierarchical protocols, and analyzed the advantages and disadvantages of each of them. In [21], by focus on studying WSN, they have used a communication protocol, i.e. LEACH protocol. LEACH is particularly effective in increasing the node lifetime. [24] presents a categorization of clustering algorithms with effective energy in wireless sensor network and provides schedule and some explanations of LEACH and its generation in wireless sensor network. Characteristics and efficiency of issues related to all hierarchical routing protocols were compared in [11] and some defects of LEACH protocol were investigated. LEACH protocol was fully compared to PEGASIS protocol in [14]; and LEACH, PEGASIS and VGA protocols were compared in [15]. Finally, it was found that LEACH protocol performs well for less than 100 nodes. For 120 nodes, PEGASIS protocol reaches the highest efficiency among these three protocols. M-LEACH was introduced in [4] and in each round adds some features to LEACH for supporting mobile nodes and decreasing network resource consumption. Simulations show that this protocol significantly decreases network's energy consumption, comparing to LEACH. [5] has introduced LEACH-FL protocol, which is an improved form of LEACH protocol using fuzzy logic. Algorithm suggested in [6], which is based on LEACH algorithm, resolves extra transmissions of LEACH. V-LEACH was provided in [7] and the objective of this new version is to decrease energy consumption in sensor network. In this version, the number of messages produced by V-LEACH protocol is less than LEACH, which means network's remaining energy by C-LEACH is more than network's remainder energy by LEACH. In [9], decreasing energy consumption of wireless micro sensor networks was investigated and LEACH protocol was adjusted. By doing so, depending on network architecture, network lifetime will be increased by 30%. In addition, it provides a new method to define lifetime of micro sensor networks using three new criteria of FND (First Node Dead), HNA (Half of Nodes Alive) and LND (Last Node Dead). U-LEACH is a uniform distribution technique (UDT) for selecting cluster heads and related clusters, which was introduced in [10] and its objective is to establish a wireless sensor network in which, each sensor node remains inside the cluster heads' transmission limit; therefore, the network lifetime is increased. [25] introduces a new protocol in the name of Kmedoids (K-LEACH), which was provided for clustering WSN, to increase the lifetime of sensor networks with balanced energy consumption in nodes. Suggested protocol uses the kmedoids algorithm for uniform clustering and maximum remainder energy (MRE) for selecting the cluster head (CH). LEACH advanced rectangular area: AZR-LEACH was introduced in [26] and uses static clustering for effective selection of cluster head. LEACH protocol, a sequential routing protocol for low energy consumption (LEACH-CC) was suggested in [19], in which each node sends the data related to the current position and energy level to the base station that consequently decreases network lifetime and energy consumption. The condition of better performance of LEACH - C regards energy and power, comparable to LEAC, was investigated in [3]. It was also fully investigated in [2] and simulation results based on lifetime and delay were analyzed. It can be mentioned that LEACH is preferred, in case that local coordination of nodes in clustering is completed without interference of BS; and LEACH-C can be selected when centralized and definite methods cover the whole process, and it is expected that the lifetime and the number of optimum clusters is increased. In [8], LEACH protocol - which is a cluster based protocol - was compared to three adjusted versions of this protocol (LEACH-C, ER-LEACH, and LEACH-SM), which extend the network lifetime. The comparison result is that the ER - LEACH protocol has a better performance regarding load balance and number of messages in a cluster. In order to restrict the energy consumption, [20] has provided a new method, which was suggested for optimizing the low energy comparative hierarchical clustering (OLEACH) to improve LEACH and LEACH-C by selecting the cluster dynamically based on the remaining energy of the node. Clustering protocol with definite effective energy (DEC), which has a definite model, was introduced in [1] that is more effective than LEACH protocols regarding energy. Effectiveness parameters like the

numbers and waste of energy in LEACH and DEC were determined and analyzed by changing the covering area, the length of packages and nodes, which indicate better performance of DEC protocol, comparing to LEACH protocol. [12] fully investigates wireless sensor networks, evaluates the hierarchical protocols, and finally provides an improved model of DEC protocol. Regarding the works done in this area, it seems that several researchers have studied LEACH protocol because of its numerous advantages, and researchers - by making small changes - have developed several versions of it with better performance. In this study, LEACH-C protocol - as a more complete version of the LEACH protocol with equal distribution of cluster heads in the network, which decreases energy waste and increases the network lifetime - will be combined with DEC protocol, in which the cluster head selection is calculated based on the remaining energy of each node and is more stable and stronger than probabilistic models. In addition, DEC outperforms LEACH regarding the waste of energy; hence, it results in increased network lifetime. In previous research, these two protocols have been investigated individually and have been improved, while the present study has worked on combination of improvement of these two protocols, and it shows innovativeness of this study.

3. RESEARCH METHODOLOGY

In this study, the descriptive-analytical approach was carried out as a research methodology based on the proposed model. The proposed model was combined with two algorithms of LEACH-C and IDEC. In this study, results of LEACH, LEACH-C and DEC were compared. At first, we investigate the protocols of wireless sensor networks. Among the probabilistic models of wireless sensor networks, we approved the relative excellence of LEACH and decided to improve its performance. Among the improvements carried out on this protocol, the LEACH-C protocol was selected. Finally, a comparison was made between LEACH protocol and its improved form (LEACH-C) that LEACH-C protocol was considered prominent. On the other hand, among the definite protocols of wireless sensor network, we selected DEC protocol, in which the cluster head selection occurs based on the remaining energy in each node. We proposed its improved version as IDEC. Finally, we combined two protocols of LEACH-C and IDEC and a comparison was made between this protocol and LEACH, LEACH-C, DEC and IDEC in order to improve the performance of this combined protocol. Finally, we concluded that the combined protocol outperforms others (Flowchart 1).



Flowchart 1: IDEC-LEACH-C Hybrid Energy Efficient Protocol (proposed protocol)

The real world experimental data were obtained from 154 Mica 2Dot5 sensor nodes present in 2Intel Berkeley research laboratory, from Feb 25 to Apr 5 2004. Sample data of temperature, humidity, light and voltage was being developed every 31 seconds. Particularly, data was selected from three representative nodes: first floor, a garret and basement. The reason for selecting these nodes is that in order for evaluation, temperature and humidity changes in the building should be investigated in these three parts [12]. Data of this comparison correspond with Table 1. The network was considered a

matrix. N is the number of nodes, which was determined 100. The probability of the best choice in selecting a node from being clustered head (P) was considered 0.05 and the initial energy was considered 0.5. The coordinates of sink node were also determined. The maximum number of rounds was assumed as 10000. The size of packages was considered 10000

Table 1: Research data

Simulation parameters	Value
$x_m \times y_m$	500×500
N	500
P	0.05
$sink.x$	0.5× $\boldsymbol{x_m}$
$sink.y$	0.5× $\mathbf{y_m}$
E_o	0.5
r_{max}	10000
Packet	10000

To calculate the energy consumption of each cluster head (Energy _ CH) the distance was compared to do value, that do value was obtained using the following equation:

$$do = sqrt(Efs/Emp)$$

Where, Emp and Efs were transmission reinforcers. In case that distance > do, Energy_ CH will be calculated by the following equation:

$$Energy\_CH = (ETX + EDA) \times (Packet) + Emp \times Packet \times (distance \times distance \times distance \times distance)$$

Otherwise, if $distance <= do$:

$$Energy_{CH} = (ETX + EDA) \times (Packet) + Emp \times Packet \times (distance \times distance);$$

Where, the amp is transmission reinforcer and EDA is energy aggregation data. However, consumed energy of each node was calculated by comparing the shortest distance to do, as follows:

If min_dis > do; then:

$$Energy\_member = ETX \times (Packet) + Emp \times Packet \times (\min dis \times \min dis \times \min dis) - (1/4000) \times ((Emp \times Packet \times (\min dis)\text{^}(0.01));$$

Otherwise, $\min dis <= do$, then Energy_member can be calculated as follows:

$$Energy\_member = ETX \times (Packet) + Emp \times Packet \times (\min dis \times \min dis) - (1/4000) \times ((Emp \times Packet \times (\min dis))\text{^}(0.01));$$

That attains the optimum results much better and faster than previous methods.

4. RESULTS

Two protocols (LEACH and LEACH-C) were compared in MATLAB software and the results were provided in the following graphs. In "Fig.1", the comparison relates to the number of nodes alive, in which LEACH protocol slightly outperforms LEACH- C protocol.

In "Fig. 2" the comparison relates to data transmission and it is obvious that LEACH-C has better performance.

The next comparison was done regarding the energy consumption. As it can be seen in "Fig. 3", two protocols have the same performance regarding energy consumption, only LEACH- C slightly outperforms.

"Fig. 4" shows the comparison regarding the number of cluster heads on two protocols that LEACH- C slightly outperforms in this regard.

The last comparison that was presented in "Fig. 5", relates to balance of the load, that LEACH- C makes so much overload when operating cluster head and it is a weakness for this protocol.

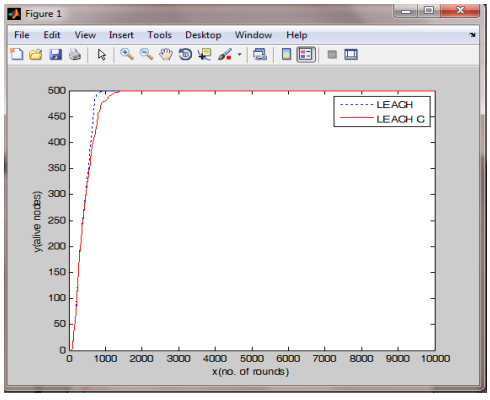


Fig. 1: Comparing the protocols LEACH and LEACH-C regarding the number of nodes alive

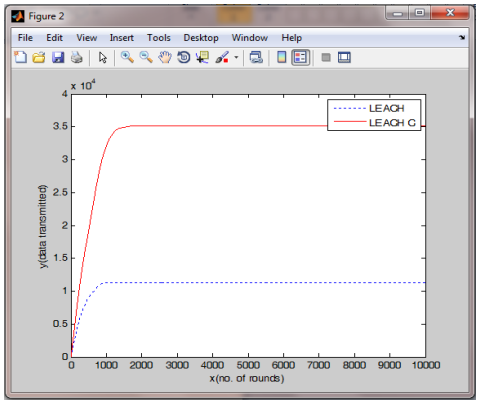


Fig. 2: Comparing protocols LEACH and LEACH- C regarding data transmit

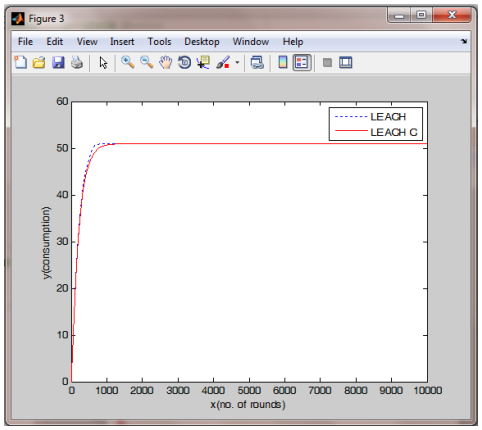


Fig. 3: Comparing protocols LEACH and LEACH- C regarding energy consumption

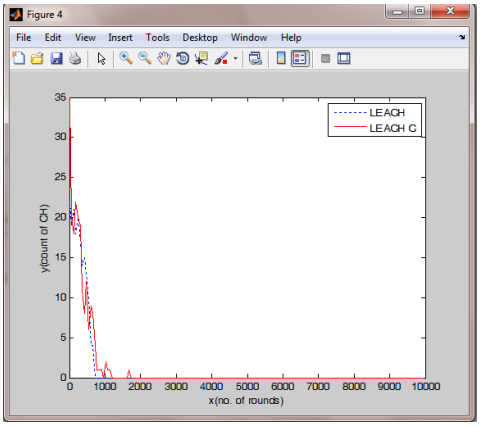


Fig. 4: Comparing protocols LEACH and LEACH- C regarding the number of cluster head

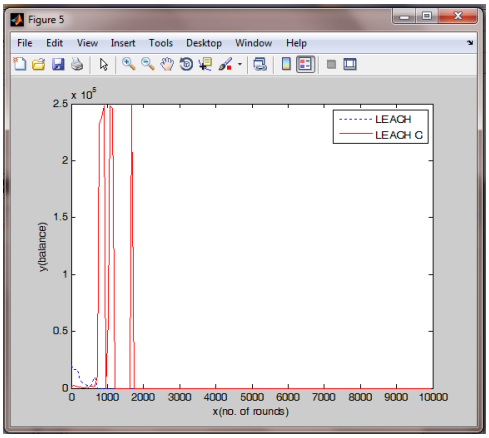


Fig. 5: Comparing protocols LEACH and LEACH- C regarding load balance

As it can be seen in the Figures, LEACH- C protocol outperforms LEACH protocol regarding data transmission and load balance and they both have an equal performance regarding the number of cluster head. Only regarding the number of nodes alive and energy consumption, LEACH protocol slightly outperforms LEACH-C. Hence, LEACH-C protocol generally outperforms LEACH protocol. In the comparisons carried out in recent years' articles and according to our results, LEACH-C protocol outperforms LEACH protocol. IDEC protocol has better performance compared to DEC. According to the results, we have decided to combine LEACH-C and IDEC protocols to achieve better results. The combined suggested model is a combination of two protocols of LEACH-C and IDEC. This combination was carried out in MATLAB software. In this combined model, energy consumption of each cluster head was calculated as follows:

- The result of performing IDEC, DEC, LEACH-C and combined IDEC & LEACH-C protocols were investigated and obtained results are presented in the following graphs. In DEC protocol, two cases of cluster head's consumed energy and each node was not measurable; hence, their value was considered zero.
- The aforementioned protocols were investigated regarding consumed energy of each cluster head and as can be seen in "Fig. 6" and values of the table, LEACH-C has the highest amount of energy consumption and our combined protocol has the least amount of energy consumption, compared to other protocols.

The result of comparing aforementioned protocols regarding energy consumption in each node was presented in "Fig.7" Investigating these results, we find out that our combined protocol has the least amount of energy consumption.

As we know, decreasing the distance between a node and its adjacent nodes decreases the energy consumption. The result of investigating the shortest distance between protocols is available in "Fig. 8" Therefore, the proposed combined protocol has the shortest distance or in other words, carries out the best routing, which results in decreased energy consumption and increased network lifetime.

Increasing the number of nodes alive in a network will result in an increased network lifetime. As it is obvious in presenting graphs, we can conclude that the proposed combined protocol results in decreased energy consumption and better routing that increases the network lifetime. Therefore, we expect a significant increase in the number of nodes alive in this protocol and as it can be seen in "Fig. 9", our expectation was realized.

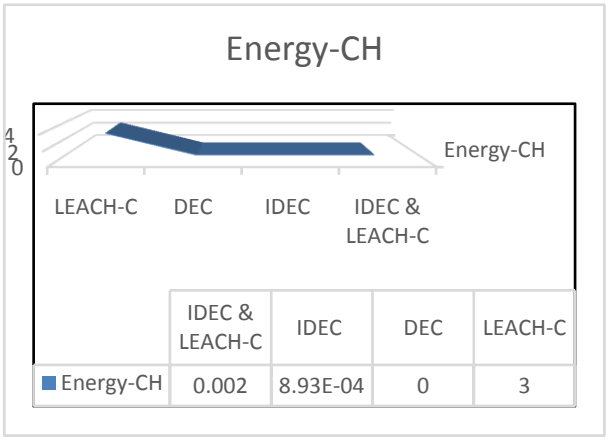


Fig. 6: Comparing LEACH-C, DEC, IDEC and IDEC & LEACH-C protocols regarding energy consumption of each cluster head

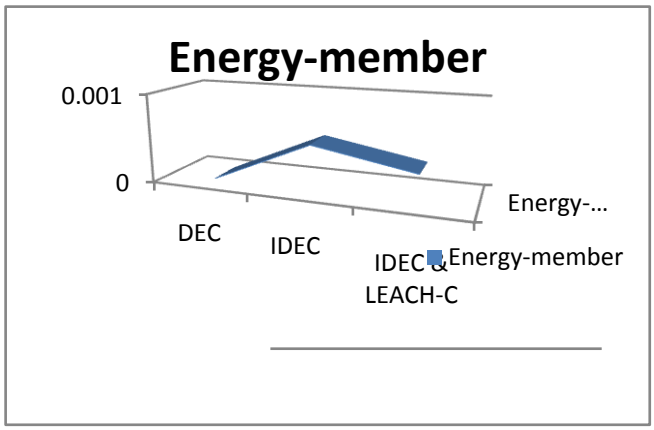


Fig. 7: Comparing DEC, IDEC AND IDEC & LEACH-C regarding energy consumption of each node

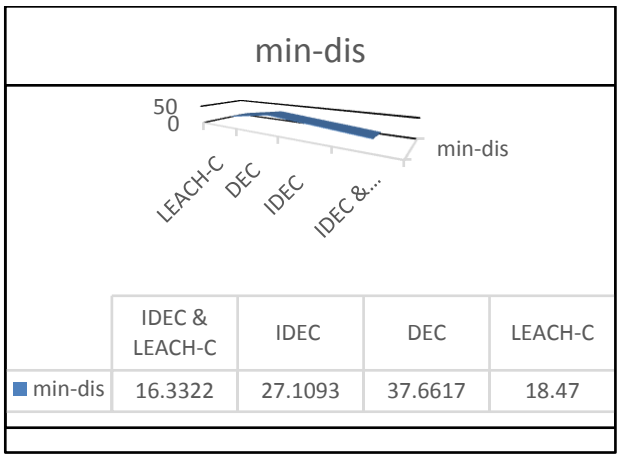


Fig. 8: Comparing DEC, LEACH-C, IDEC and IDEC & LEACH-C protocols regarding the shortest distance

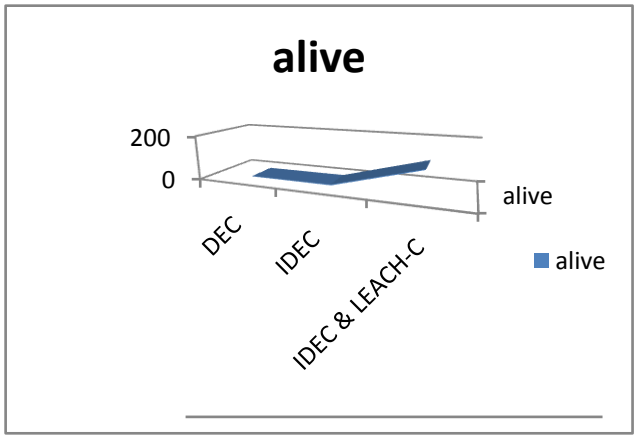
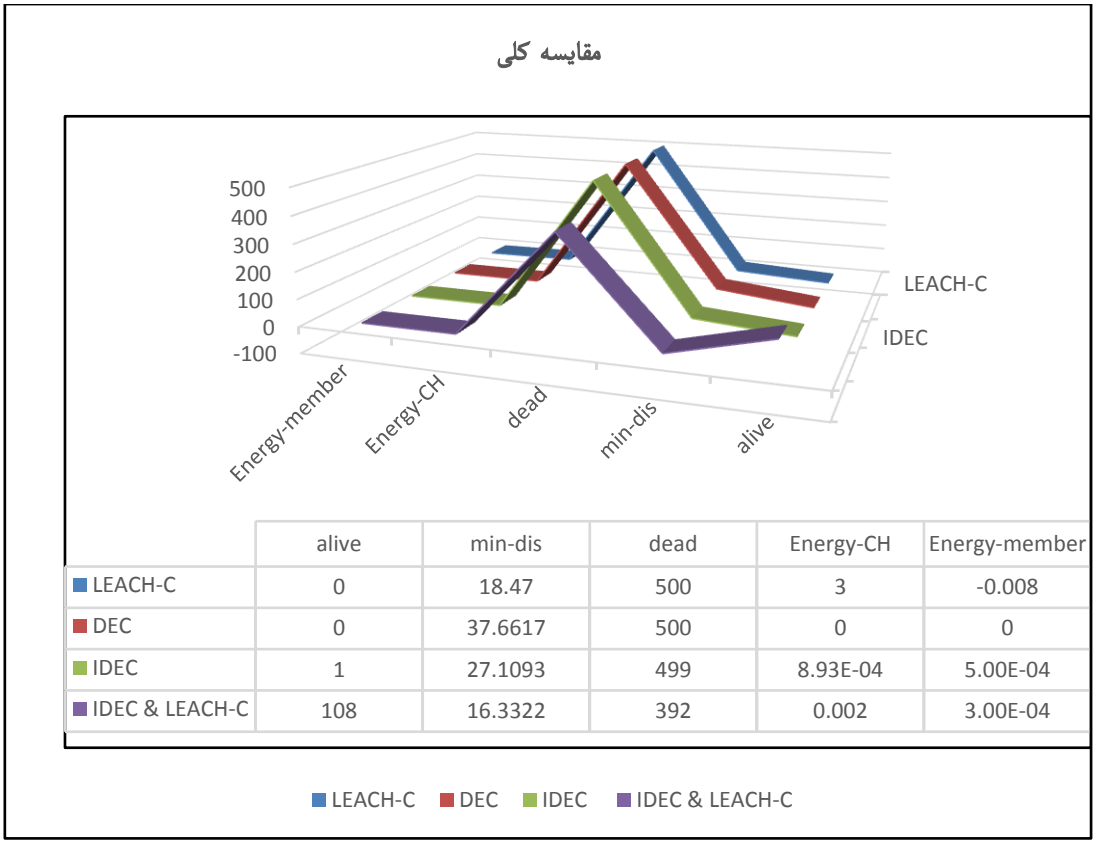


Fig. 9: Comparing DEC, LEACH-C, IDEC and IDEC & LEACH-C protocols regarding the number of nodes alive

As it can be in the graphs, LEACH-C protocol outperforms LEACH protocol. Furthermore, the improved DEC protocol has a significantly better performance compared to DEC protocol, and the combined IDEC &LEACH-C has the best performance. Finally, the general comparison was presented in "Fig. 10".



	alive	min-dis	dead	Energy-CH	Energy-member
LEACH-C	0	18.47	500	3	-0.008
DEC	0	37.6617	500	0	0
IDEC	1	27.1093	499	8.93E-04	5.00E-04
IDEC & LEACH-C	108	16.3322	392	0.002	3.00E-04

Fig. 10: General comparison of DEC, LEACH-C, IDEC and IDEC & LEACH protocols

As it can be seen in the Figures, the proportion of nodes alive to nodes dead was increased and subsequently the number of nodes dead was decreased. The distance was decreased, which results in decreased energy consumption. Energy consumption of each cluster head was decreased compared to LEACH-C and DEC protocols; however, it has a slight increase compared to IDEC protocol; and calculating the nodes alive, this amount of wasted energy is acceptable for this number of nodes alive. The last computational factor is the energy consumption of each node, which was also decreased significantly, compared to other protocols.

5. DISCUSSION AND CONCLUSION

The objective of the present research is to decrease energy consumption in clustering the wireless sensor networks. In this research, we compared LEACH and LEACH-C protocols. The results indicated that LEACH-C protocol outperforms LEACH protocol. According to the results of this study, it was observed that the proposed protocol outperforms other protocols. Protocol IDEC&EACH-C decreased the energy consumption. As we know, decreased energy consumption results in increased network lifetime. In this protocol, the number of nodes alive was increased and consequently the number of nodes dead was decreased. The distance was decreased, which results in decreased energy consumption. Energy consumption of each cluster head was decreased comparing to DEC and LEACH-C protocols; however, it has a slight increase compared to IDEC protocol; and calculating the nodes alive, this amount of wasted energy is acceptable for this number of nodes alive. The last calculation factor is the energy consumption of each node that was significantly decreased compared to other protocols.

In this study, a probabilistic model was combined with a definite protocol. The combined protocol, DEC&LEACH-C, reduces energy consumption and finally extends the network lifetime. This protocol increased the number of nodes alive, compared to other protocols that increased number of nodes alive, results in increased network lifetime. The proposed protocol decreased the transmission distance, which finally results in reduced energy consumption. The combined protocol decreased the amount of energy consumed by each node, comparing to other protocols. This protocol, comparing to LEACH-C and DEC protocols, decreased the energy consumed by each cluster-head, but increased the energy consumed by each cluster head, compared to DEC that by calculating the number of nodes alive, this wasted energy can be accepted for this number of nodes.

In this study, we optimized the energy consumption; however, it may increase the duration of transmitting data from one node to another, because we have not investigated the time. The network traffic was not investigated, either. Increased or decreased traffic on the network can influence the research results.

The combination of protocol DEC&LEACH-C with other protocols, which have an effective performance in clustering the wireless sensor networks, was suggested for decreasing the energy consumption and extending the lifetime of wireless sensor networks. As we know, the network traffic was not investigated in this research. Future researchers can investigate the network traffic, using the Queuing Theory.

6. ACKNOWLEDGMENTS

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