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A Novel Approach for Energy Optimization of Wireless Sensors Network by Adaptive Clustering

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Abstract—Energy optimization has a major role in modern researches. While, energy optimization of wireless sensors network is the most important, because of the limitations of the battery energy of the wireless sensor. This paper concentrate on energy optimization by introducing a novel and an adaptive clustering algorithm that is fuzzy logic based. The result of our work minimizes the interval between the first node (sensor) death and the last one. The dead node interval minimization to a value near to zero increases the efficiency of energy and saves 93% of traditional clustering of wireless sensors network. This paper compares the result of this novel approach to LEACH, LEACH-M, and LEACH-L algorithms.

Keywords-Wireless Sensors Network; LEACH; Energy Efficient; Fuzzy Clustering.

I. INTRODUCTION

Wireless Sensor Networks can collect reliable and accurate information in distant and hazardous environments, and can be used in National Defense, Military Affairs, Industrial Control, Environmental Monitor, Traffic Management, Medical Care, Smart Home, etc. The sensor whose resources are limited is cheap, and depends on battery to supply electricity, so it's important for Routing to efficiently utilize its power.

This paper proposes an advanced modification on [1]. The modification is fuzzy logic based clustering algorithm which can be described as follows: calculate a potential of all nodes which is given in equation 1. Start determining the cluster head by fuzzy c-mean algorithm directly. The clusters which are selected by the new modified algorithm depend on the potential of nodes. Equi-potenial clusters are assumed in this paper.

$$P = 1/Eq + 1/Er - d * tq - k \quad \ldots. (1)$$

Where: P is the potential.
Eq is the Euclidean distance, given in equation 2
Er is the total remaining energy in the sensors battery.
d is the transmission data cost function
tq is the energy slop of transmission data.
k is the battery self leakage.

$$d(p, q) = d(p, q) = \sqrt{\sum_{i=1}^{n}((q_i - p_i)^2)} \quad \ldots.. (2)$$

Where: d(p,q) is the coordinates of the nodes,
P1, q1 is the first node
P2, q2 is the second node or the head of cluster

The sensors in different areas use different frequencies and gaps to communicate with BS. In the last part, a comparison with LEACH, LEACH-M, and LEACH-L is shown. The overall work is done using MATLAB.

The simulation experiments indicate that the new contributed approach can prolong the whole network lifetime for an interested scale.

II. RELATED WORKS

A main issue in the design of wireless sensor networks is the power dissipation scheme, hence the wireless node has a

limited energy tag battery and has no backup power source until node death, thus, researches consider the design of low-power signal processing architectures, low power sensing interfaces, energy efficient wireless media access control and routing protocols, which revolves around energy balancing and management process.

LEACH is one of the first hierarchical routing approaches for sensors networks, which attempts to improve energy and routing efficiency of such networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed.

The main target research that this paper aims to compare with is [1]. That paper focuses on reducing the power consumption of a wireless sensors network, its algorithm called LEACH-L. Our work differ from that paper in that, this research is supposed to determine the original centers of all clusters using fuzzy logic based clustering, in addition, the centers of all clusters are dynamically changeable over the time, also, the cluster sizes is qui-potential clusters, the cluster arrangement may change over the time thus, the potential will be equal over the running time and the life time.

In [3], the author puts forward energy-LEACH and multihop-LEACH protocols called LEACH-M. Energy-LEACH protocol improves the choice method of the cluster head, makes some nodes which have more resi- dual energy as cluster heads in next round. Multihop- LEACH protocol improves communication mode from single hop to multi-hop between cluster head and sink. Simulation results show both energy-LEACH and our results in this paper. Our simulated results are much better than LEACH protocols.

In [4], author proposes a novel energy efficient clustering scheme for single-hop wireless sensor networks. A novel cost function is introduced to balance the load among the cluster heads and prolongs the network life-time significantly against the other clustering protocols such as LEACH. Our algorithm arranges and manages the potential of nodes to semi-equal, thus, the death of all nodes happens in the same interval, which maximizes the life time of overall network.

In [5], a novel multicast protocol, uCast is proposed for energy efficient content distribution in sensor net-works. The uCast support a large number of multicast sessions, especially when the number of destinations in a session is small. Our paper supports large number of data with relatively low computational time and power.

III. FUZZY CLUSTERING

Fuzzy C-Mean (FCM) algorithm is a away to show how data can be classified and clustered in organization or in any application such as cellular, but it's important to observe that data has some attributes such as distance between points of data, weight and potential value for data points that makes it difficult to understand how to cluster data points in such away to achieve better classification and use of data points. FCM algorithm divide data for different size cluster by using fuzzy system depending on many criteria like distances between one data point and other's, center points and membership function. Thus, the clusters don't have accurate sizes.

FCM algorithm puts each point into a cluster that is near to it by measuring the distance between point and clusters. Our algorithm has a new criterion – rather than distance, to decide if any point will be included to any cluster or not.

If a specified data point included in two clusters or more the problem is how to decide in which cluster it can be used? This problem is so important in the proposed application; because of that, any point located between two clusters can be excluded or included by those clusters. In this paper, the balance of cluster means that, making all cluster sizes equal by adding or excluding one point (node), two points, or three points. The balance of clusters depends on the points that are located in between two or more clusters with semi-equal potential.

The traditional clustering using FCM algorithm puts all points into a specified cluster, resulting in different clusters sizes. This paper relates the points to its cluster depending on its potential regardless of it's arrange.

IV. METHODOLOGY

This paper's methodology is divided into three procedures; the first is clustering the data depending on fuzzy c-mean clustering algorithm in order to determine initial head of clusters. All nodes will be distributed in clusters depending on the initial potential of all nodes which is calculated by equation 1, and on the head of clusters whom achieved by fuzzy logic.

The second procedure is start transmitting data from the cell nodes to the base station across the head of the cluster.

Energy of all nodes will be changed after the transmission process. The amount of energy that the node loses in each transmission process is called "energy slope".

The third procedure is to re-select all head of clusters by using equation 3, and re-distribute the overall nodes on the clusters to ensure that all clusters have equal potentials over the whole life time.

$$Pc = \min (Pco \sum (Pco - 1) + (Pco + 1)) \quad \ldots\ldots \quad (3)$$

Where Pc is the next cluster head potential (goal) and Pco is the current cluster head potential.

This topology is dynamic and the clusters is changed every transmitting process.

Figure 1 shows a sample topology after clustering. The nodes which have two colors (i.e. blue and black) is located in between two clusters (i.e. the nodes that have blue and black colors, can be added to the blue cluster or even to the black one). Including a single node to a cluster will not cause a big change, but it will balance the cluster potential.

Figure 1 shows four clusters; Black, Green, Blue and Red. The bold large node is the cluster head. The in between points (that have two colors) are transient points which can transmit between two clusters continuously every new clustering process.

The potential of all clusters will not get exactly equal, but it will be goes to appear equal, hence, the difference between clusters potential is very small and may be negligible. Otherwise, the size of those clusters will be different.

The size of clusters doesn't take place in this proposed algorithm.

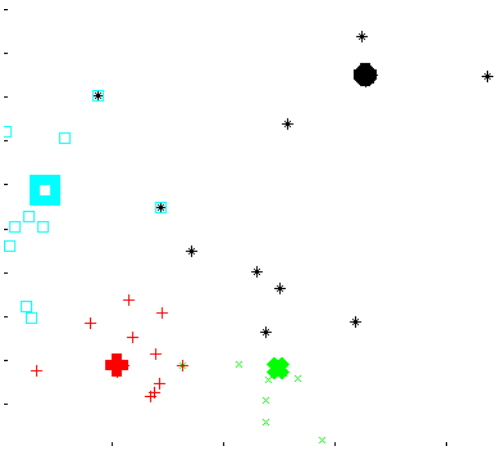

Figure 1. Sample of the proposed topology for wireless sensor network.

This few change will got at least 3% life time extend for the overall node.

Nodes death interval can be long as LEACH or LEACH-M approaches. When a first node is dead, the data collection of that sensor will be stopped as long as gathering and logging. In addition, transmission of information will be interrupted for some processes. The nodes death interval is the period from the first node death to the last node death in the network. This period should be as small as possible.

The long interval of nodes death is a big deal in wireless sensors network. It results in either energy losses or data losses. There are many approaches aim to deal with that interval. This paper aims to minimize that interval in the best way.

The developed system in [1] minimizes the interval of nodes death in LEACH-L algorithm which results in a non negligible ratio of total energy saving. But still has an interval of node death that causes losses in the transmitted data in addition to the losses in energy over a relatively wide time.

Our algorithm developed more efficient system than LEACH-L algorithm. It contributes a modification that minimizes the time of nodes death interval to most known shortest interval. Hence, this algorithm distributes the nodes on clusters those has equal potential, which minimizes the load on many nodes and ensures symmetric energy slope.

An addition, considering the head of cluster to be the maximum potential node will minimize the consumed energy of some nodes.

Actually, selecting the head of cluster in a non-optimal way may consume its energy in a very short time while the proposed technique is saving the head of cluster energy.

However, there is still a difference in the remaining energy of the actual nodes in each transmission process; this will be clear when testing on large transmission scale of data. That difference will represent real challenges for future researches because it needs to develop a new algorithm.

V. RESULTS

This paper developed an algorithm using MATLAB to experiment and simulate the proposed procedure. The

parameters of test conditions and experiments are shown in Table I.

In the simulation, we have used the same parameters and conditions that were used in [1], in order to make the comparison meaningful. The new modification and improvement of results, especially energy, is clarified by the following figures.

TABLE I. SIMULATION PARAMETERS.

Parameter	Scene 1	Scene 2
The scope	300 x 300 m	500 x 500 m
The number of sensors	900	2500
The initial energy	0.5 J	0.5 J
E	1J	1 J
The length of packets	4000	4000
E_{TX}	5×10^{-8}	5×10^{-8}
E_{RX}	5×10^{-8}	5×10^{-8}
ε_{fs}	10^{-11}	10^{-11}
ε_{mp}	1.3×10^{-15}	1.3×10^{-15}
E_{DA}	5×10^{-9}	5×10^{-9}
P	0.1	0.1
M	0.1	0.1
D	70 m	70 m
Restriction_distance	30 m	70 m
Max_distance	87 m	87 m

Figure 2 shows the life time cycle over round of 300 by 300m. It shows the node death scheme for LEACH, LEACH-M, and LEACH-L, and also, it shows the results of the proposed system which results in saving energy and extending the life time of the nodes. Minimizing the interval of overall nodes death is clear from the figure.

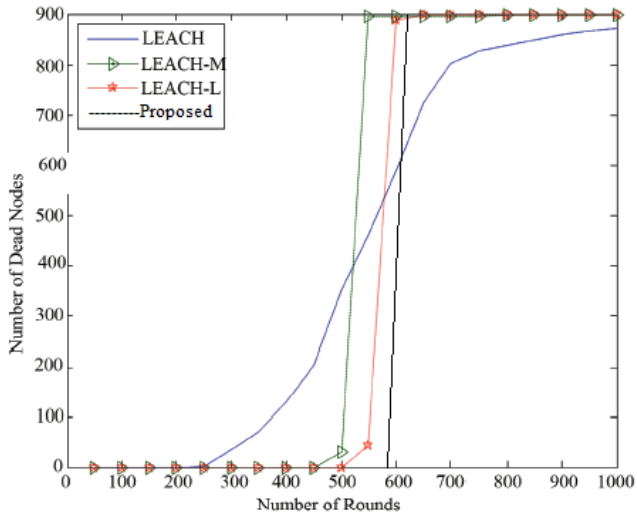

Figure 2. Dead nodes over round of 300 x 300, among LEACH, LEACH-M, LEACH-L versus the Proposed Algorithm.

Figure 3 shows the received packet number of LEACH, LEACH-M, and LEACH-L over a round of 300 x 300m, and also, it shows the same data with respect to the proposed approach. It ensures the keeping of packet transmission in addition to longest packet amount.

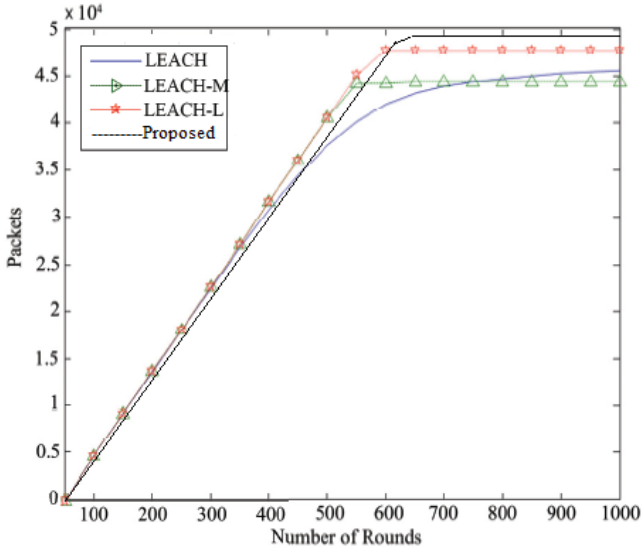

Figure 3. Received packets over round 300 x 300 among LEACH, LEACH-M, LEACH-L versus the Proposed Algorithm.

Figure 4, 5, and 6 shows the energy consumption of LEACH, LEACH-M and LEACH-L, over round of 300 x 300m, and 500 x 500m respectively, in addition to the same results of the proposed algorithm.

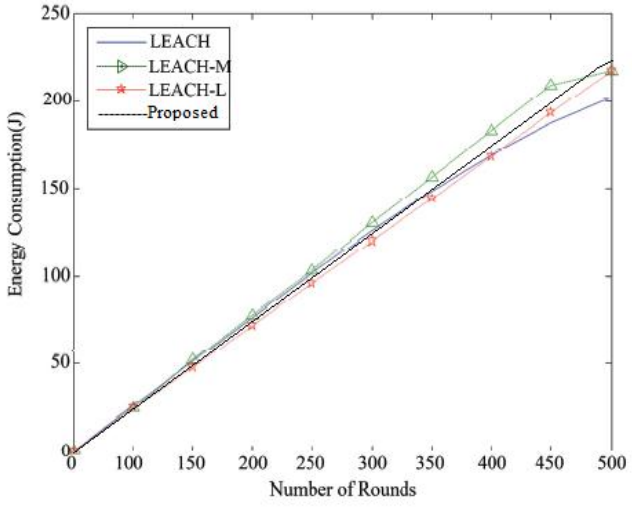

Figure 4. Energy consumption among LEACH, LEACH-M, and LEACH-L over round of 300 x 300 versus the Proposed Algorithm.

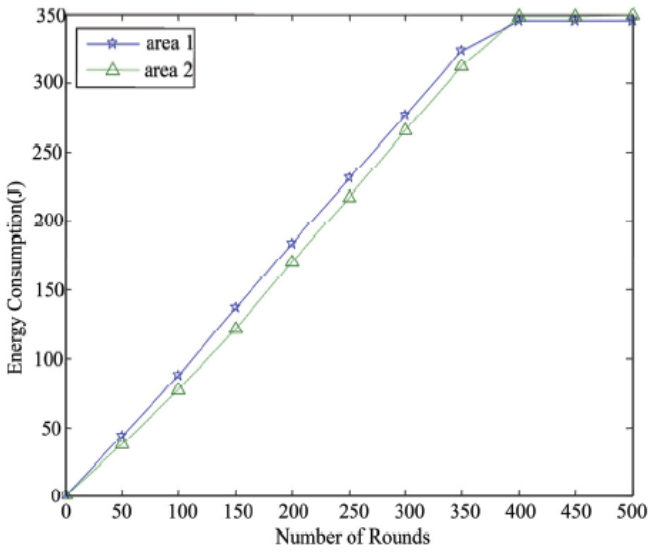

Figure 5. Energy consumption among LEACH, LEACH-M, and LEACH-L over round of 500 x 500.

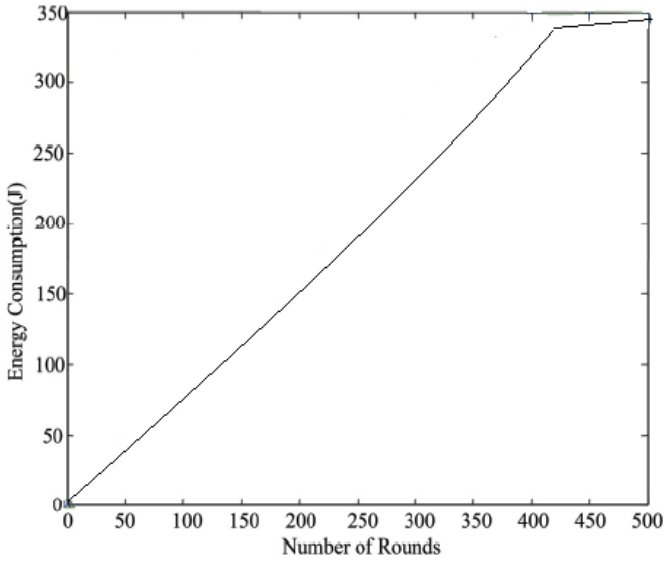

Figure 6. Energy consumption among this paper over round of 500 x 500.

These figures show that the energy amount is extended over a longest time. Hence, the battery backup energy that the sensors hold is constant in all approaches (this paper approach and the old approaches) then, the energy can extend over a time instead of consuming it over a short period.

Figure 5 and 6 shows that this approach uses less energy in time unit and thus, extends the total backup energy holding in the sensor over the time.

VI. CONCLUSION

The wireless sensor network has a structure that needs a specified energy balancing design and optimization.

It's clear from our research that, the energy can be optimized in clustering and managing the data transfer across over all process. Energy management can be done by typical distribution of nodes with respect to clusters and optimal selection of the head of cluster.

This paper introduces and implements a new methodology of clustering and managing the transfer amount on the potential of each node and the overall potential of each cluster, with varying cluster head over time.

The results show that the energy losses have been decreased and thus the life time of all nodes increased in an interested amount. Hence, all nodes will be dead at the same time which means that there is no data lose.

The use of fuzzy logic in clustering makes the system design simpler and got better fast results, in addition to minimizing the mathematics complexity of the system's design.

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