A New Algorithm for Cluster Leader Selection in Wireless Sensor Networks

Mehdi Gheisari

May 3, 2022

A new algorithm for cluster leader selection in wireless sensor networks

Abstract: Nowadays sensors play nearly a crucial role in our daily lives. As one of the most important impacts that we can point to is an investigation of non-reachable places for humankind, etc. Sensor networks consist of tiny sensors that can be homogenous or heterogeneous. Sensors cannot be managed by a human. So they have to be self-managed. Most of the Sensors work with low-producer-power, like a battery.

Keywords: Fuzzy Logic, WSN, Clustering

1- Introduction

Wireless Sensor Networks are widely used in various civil and military related applications. One of the most challenging issues is to manage nodes in environments that basically cannot be reached or when it's not possible to replace their power source. Many of WSN nodes today are supplied with rechargeable lithium ion/polymer batteries and polycrystalline cells to charge them by ambiance sunlight radiation. They include a variety of sensors such as temperature, humidity, motion detection, light, UV or IR sensors. A pico-power microcontroller manages the node and a CMOS low power transceiver to provide the communication layer. However, the most hesitating part is to recover the captured information from dead nodes and to guarantee the transmission of captured data safely to the base station.

2-Literature Review:

Qi Dong and Donggang Liu in [1] describes a new and novel distributed cluster head leader selection algorithm based on symmetric key operations that have three main characteristics: cluster nodes are consistent in cluster leader selection, relatively resistant against attackers which mean attackers do not have any impact on benign nodes for cluster leader election decisions, and the last is a fault tolerant algorithm which recovers messages that may be lost or changed via malicious attacks.

Puneet Azad, etc in [2] presents a new cluster head election algorithm that is based on fuzzy rule and also considered three main characteristics: remaining energy of nodes, number of neighbors, and distance from the base station or sink node, comparing the proposed method with the distributed hierarchical agglomerative clustering and showing it has better performance in network lifetime. Dilip Kumar in [3] introduces a new distributed stable algorithm that is used for cluster head election. The presented algorithm, DSCHE, which is based on weighted probability, considers two aspects: remaining energy and the average energy of network, he showed that the algorithm is more stable and has better performance in comparison with conventional ones. One of the main drawbacks of this algorithm is the volume of data packets sent to Base Station rather than some of the known algorithms. Sohail Jabbar in [4] introduces a multilayer algorithm for clustering.it means that three centralized and distributed algorithms are considered in order that they will reduce the number of cluster head candidates. To achieve this goal, the centralized algorithm is used or distributed one can be used. It also reduces message exchange and uses communication architecture and design architecture.

3-Use fuzzy inference systems in clustering

Fuzzy logic is a useful decision-making system, which used in many fields of engineering. It is not necessary to have complete information about the environment in Fuzzy logic based systems. On the other hand, the normal control mechanisms generally require accurate and complete information about the environment.

Fuzzy logic can make decisions based on a variety of environmental parameters, combining them according to predefined rules which are used.

Some clustering algorithms use fuzzy logic to overcome the problem of uncertainty in wireless sensor networks.

The fuzzy clustering algorithm (FCA) uses fuzzy logic to combine different parameters to select a cluster head.

In accordance with a de-fuzzy output of the system, they report the chances of cluster head that is achieved with IF-THEN rules.

A node will be a cluster head if it has the most chance to their adjacent nodes.

Fuzzy logic methods can be distributed or centralized. In this paper, we try to use the fuzzy system to solve the problems of previous systems and presenting the, based on authors knowledge, optimal algorithm to select the cluster head. The proposed clustering algorithm is based on LEACH whose functionality and reliability are improved by fuzzy systems.

LEACH Protocol is one of the first and most famous hierarchical protocols that is Provided for wireless sensor networks.

In this protocol, Network activity is divided into time periods (Figure 4).

At the beginning of each period, the number of nodes as a cluster head is selected randomly.

For this purpose, each node produces a random number between 0 and 1.

If this number is less than the T (n) that is achieved using Equation 4.3, the node as cluster head is introduced.

In relation (4-1), P is ratio of the number of clusters and the total number of network nodes,

r is number of Course,

And G is the numbers of nodes in the 1 / P previous are not selected as cluster head.

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times (r \bmod \frac{1}{p})}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

After defining the cluster head node, other nodes based on the received signal strength from each cluster head, are decided to become a member of each cluster.

Cluster head node divides the range of their responsibilities into several time slices.

This time slices are sharing based on TDMA mechanism between members of the cluster.

In each time slices, cluster head communicates with one Cluster's members and receives its information packets.

In some time slices, Cluster head sends received Information from its members to the central node. In order to distribute the load on different nodes after a period, for the beginning of a new era, cluster head based on the mechanism described above is changed.

In short, the LEACH algorithm is as follows:

Notification phase (advertising): Each sensor selects a random value between 1 -0.

If the random number is less than a threshold T (n), in this case, the node selects itself as a cluster head.

While P is the percent of needed cluster head, r is number of current period And G is a fraction of the nodes that is not a cluster head in the 1 / P last period.

Using this threshold, each node in each 1 / P period will be a cluster head.

In the first round, all nodes can be cluster head with P probability.

In the next period, the probability of selected nodes that are not selected as the cluster head can be increased.

The method presented in this study is described by fuzzy inference system that is expressed in details below!

Each node selected as cluster head node sends a message broadcast to the others.

All cluster head send the announcement messages with the same energy.

ADV = node's ID + distinguishable header

After this stage, the non-cluster head node, choose their cluster head which they belong to.

If a non-cluster head node receives several announcement messages, it will join to the close cluster head. (Closeness is detected by the strength of the received signal).

In the same case, a cluster head will be selected randomly.

Cluster formation Phase:

In this phase, each node after the determination, that is, which cluster it belongs to must deliver this issue to the cluster head of that cluster.

Join-REQ = node's ID + cluster-head ID + header.

Forming phase schedule:

At this stage, cluster head receives all Members joined messages and based on the number of them, Constitute a TDMA schedule and send information for each node.

Data transfer phase:

After the clusters were formed and fixed TDMA, Data transfer can be started.

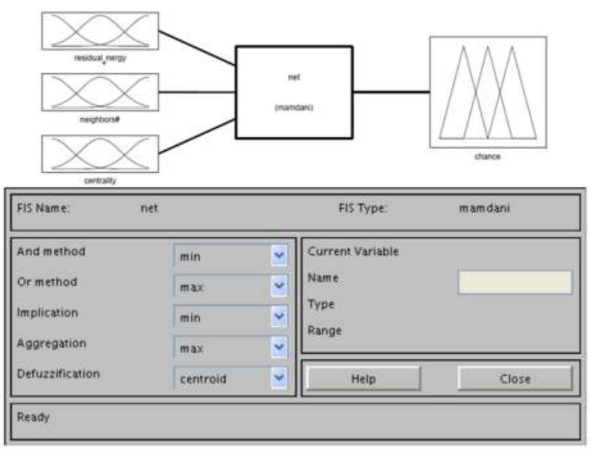
Each Non-cluster head node radio device can be turned off until the node notification time.

In the proposed method, the amount of chance of each node to the parent (phase announcement) is calculated using a fuzzy system.

The "Mamdani" type is used in the fuzzy system, with three inputs and one output.

The defuzzification of output is used to find the center of the mass method, which is the most popular method among seven defuzzification of the output.

Overview fuzzy system and its features can be seen in Figure 1.



Membership functions for the fuzzy system have been obtained experimentally and testing and optimization.

Inputs and outputs are defined as follows:

The first input (residual _energy):

The first input shows the remaining amount of energy of each node.

Whatever the amount of energy is higher, it can send and receive more information and its lifetime is higher.

The second input (neighbors #) Shows the number of each node neighboring.

Nodes that have more neighbors will have a better chance of being a parent.

The proposed method is calculated based on the number of neighbors (Qu et al., 2012). In this method, the following formula is used:

$$N = 1 - e^{-\gamma \pi R^2}$$

Where R is the radius of the neighborhood and the $0.01 = \gamma$.

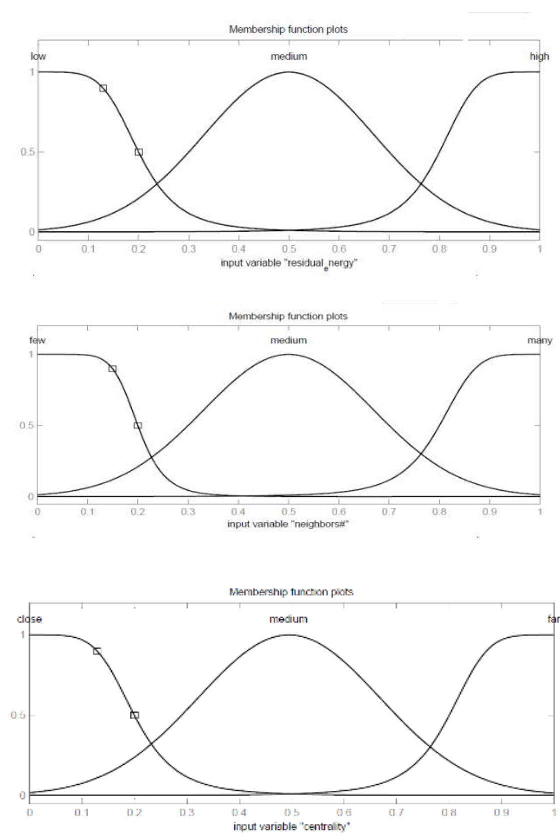
In the algorithm running neighbor, radius is considered 15 meters.

The third input (centrality) shows the distance of a node from the central node.

Less distance a better chance of becoming a parent will make.

Output (chance) combines three input value by fuzzy rules defined, the chance of a node for becoming parent node is obtained by fuzzy system output.

Input and output membership functions in Figure 2 are observed.



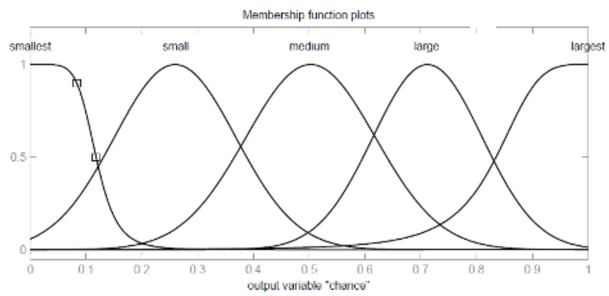


Figure 2- (a), (b) and (c) input membership functions, (d) output membership function of the fuzzy system

Input values are defined by fuzzy rules, which are combined to produce output.

For this fuzzy system 18 laws are defined as follows:

1. If (residual_energy is low) and (neighbors# is few) and (centrality is far) then (the chance is the smallest)

2. If (residual_energy is medium) and (neighbors# is few) and (centrality is far) then (the chance is the smallest)

3. If (residual_energy is low) and (neighbors# is medium) and (centrality is far) then (the chance is the smallest)

4. If (residual_energy is low) and (neighbors# is few) and (centrality is medium) then (the chance is the smallest)

5. If (residual_energy is low) and (neighbors# is medium) and (centrality is medium) then (the chance is small)

6. If (residual_energy is medium) and (neighbors# is medium) and (centrality is far) then (the chance is small)

7. If (residual_energy is high) and (neighbors# is many) and (centrality is close) then (the chance is the highest)

8. If (residual_energy is high) and (neighbors# is medium) and (centrality is close) then (the chance is high)

9. If (residual_energy is medium) and (neighbors# is many) and (centrality is close) then (the chance is high)

10. If (residual_energy is high) and (neighbors# is many) and (centrality is medium) then (the chance is high)

11. If (residual_energy is medium) and (neighbors# is medium) and (centrality is medium) then (the chance is medium)

12. If (residual_energy is medium) and (neighbors# is many) and (centrality is medium) then (the chance is medium)

13. If (residual_energy is medium) and (neighbors# is medium) and (centrality is close) then (the chance is medium)

14. If (residual_energy is medium) and (neighbors# is medium) and (centrality is far) then (the chance is medium)

15. If (residual_energy is medium) and (neighbors# is few) and (centrality is medium) then (the chance is medium)

16. If (residual_energy is medium) and (neighbors# is many) and (centrality is medium) then (the chance is medium)

17. If (residual_energy is low) and (neighbors# is medium) and (centrality is medium) then (the chance is medium)

18. If (residual_energy is high) and (neighbors# is medium) and (centrality is medium) then (the chance is medium)

An example of how to combine inputs to produce an output is observed in Figure 3 and 4.

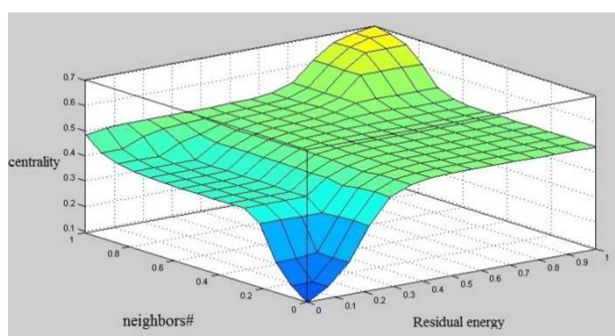


Figure 3- the combination of input parameters

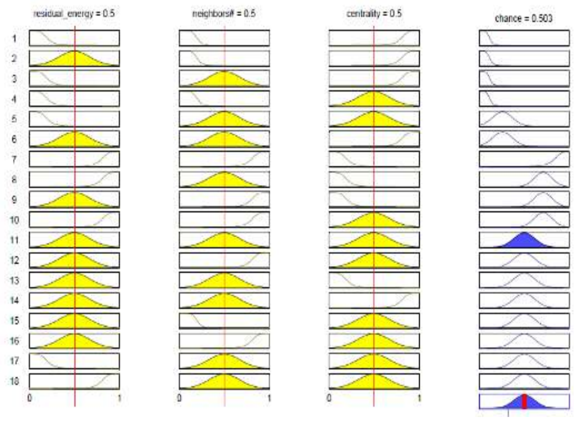


Figure 4- the combination of inputs to produce outputs

To examine the design methods, a network with 100 nodes is considered that are randomly distributed. Other network parameters are entered in the following proposed algorithm:

```
%Field Dimensions - x and y maximum (in meters)
 xm=100;
 ym=100;
 %x and y Coordinates of the sink
 sink.x=0.5*xm;
 sink.y=0.5*ym;
 %Number of Nodes in the field
 n=100

 %Initia Election Probability of a node to become
cluster head:
 p=0.1;
 %Energy Model (all values in Joules)
 %Initial Energy:
 Eo=0.5;
 %Eelec=Etx=Erx
 ETX=50*0.000000001;
 ERX=50*0.000000001;
 %Transmit Amplifier types
 Efs=10*0.000000000001;
 Emp=0.0013*0.000000000001;
 %Data Aggregation Energy
 EDA=5*0.000000001;
```

Network Model

At first, we will explain the characteristics of the system model which is used.

First, we expressed our assumptions about the Network Model.

For reviewing the designed method:

A network with 100 nodes and a random distribution is used.

The network is considered in the 100m × 100m.

Base station coordinates [50.50] are considered.

The amount of initial energy is equal 0.5 Joule.

And the initial probability is assumed to be 0.1.

All sensor nodes have the same energy in the arrangement stage.

All nodes and sink after the arrangement are fixed.

All sensor nodes have the same computing power; memory and energy or homogeneous in terms of form.

The distance between nodes can be calculated based on the intensity of the received signal. Therefore sensor nodes do not need to be aware of their exact location.

Radio energy model

Radio energy model for k-bit packet transmission, in the distance d meter, in the simulations is as follows:

$$E_{Tx}(k,d)=\begin{cases} k*E_{elec}+k*\varepsilon_{fs}*d^2, d<d_0 \\ k*E_{elec}+k*\varepsilon_{mp}*d^4, d\geq d_0 \end{cases}$$

As well as radio energy model which receives a k-bit package is as follows:

$$E_{Rx}(k)=E_{elec}*k$$

Depending on the distance, the consumed energy has been expressed in channel model by *fsε* and *mpε*.

Eelec is the amount of energy required to run the transmitter circuit or receiver.

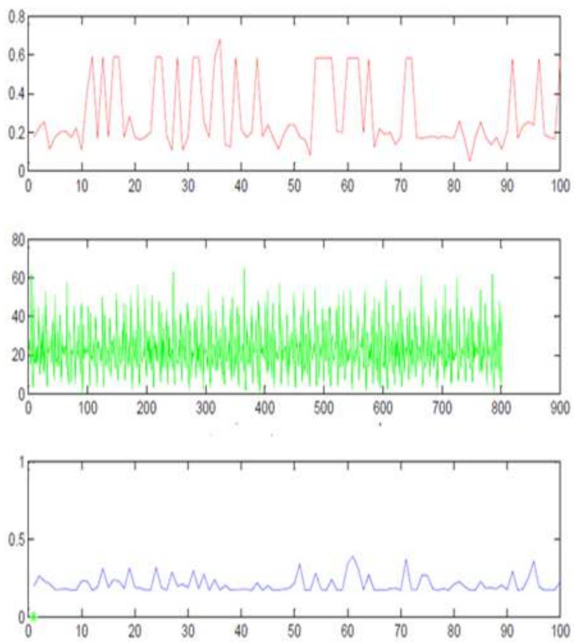
Radio parameters used in the simulation are set as follows:

E_{elec}=50 nJ/bit
EDA=5 nJ/bit/report
ϵ_{fs}=10 pJ/bit/m^2
ϵ_{mp}=0.0013 pJ/bit/m^4

Algorithms for different numbers of repetition are examined.

After about 1,000 rounds the optimal cluster head, will be achieved.

Figure (5) show the changes of system parameters during the repetition.



Distance

Number of CH

Probability

Figure (6) shows the resulting output, this system is applied at 800 rounds for 100 nodes with a random distribution. Table (1) shows four-run simulations to compare the lifetime of the proposed method and LEACH.

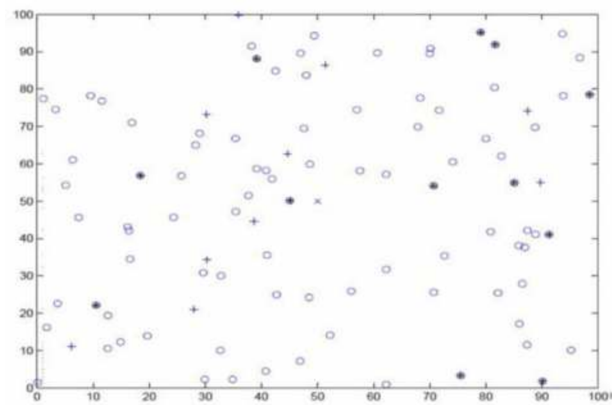
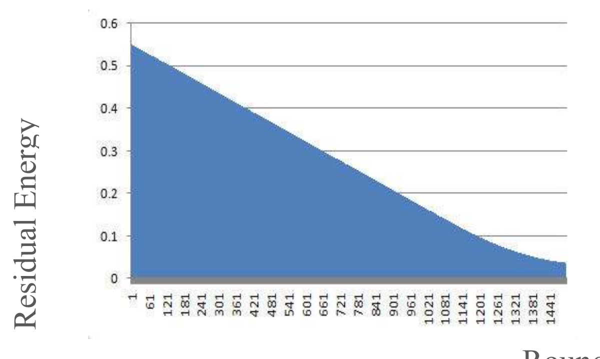


Figure (6) - Clusters achieved for random 100 nodes and a network of m 100 * 100

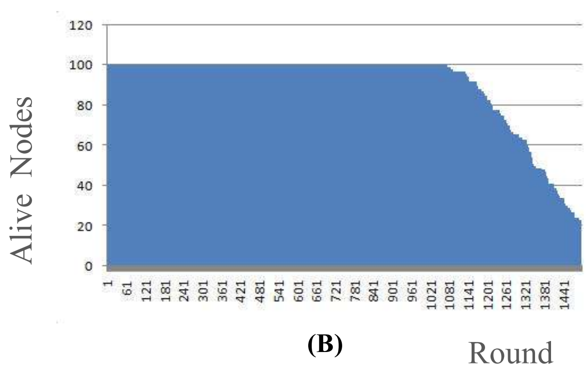
Table 1- lifetimes Comparison between proposed algorithm and LEACH

	First Run	Second Run	Third run	Fourth run
LEACH	1441	1497	1509	1417
PROPOSED	1696	1659	1704	1651

Figure (7) Part (A) shows the remaining energy and (B) number of live nodes.



(A)



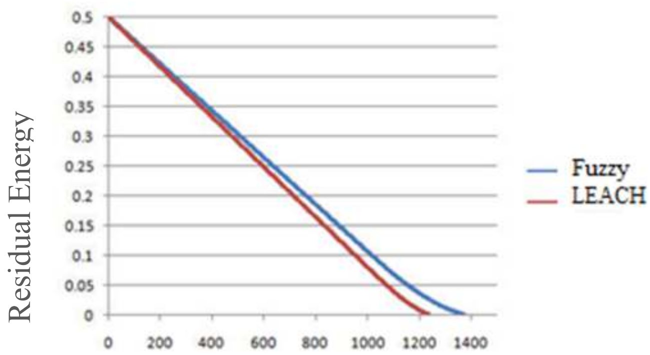
(B)

The results showed higher accuracy compared to conventional LEACH algorithm.

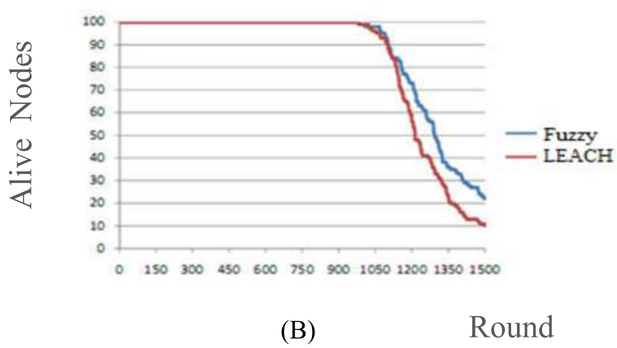
Figure (8) standard LEACH algorithm comparing with the proposed algorithm by the fuzzy system.

Part (A) shows the remaining energy and (B) number of live nodes.

As you can see, using the fuzzy system has caused improvement in these two parameters.



(A)



(B)

Another new work in this area by (Godbole, 2012) has done.

This algorithm (FCA) is designed for wireless sensor networks that sensor nodes are fixed.

This algorithm adjusts the radius of the cluster head with respect to the residual energy and distance sensor nodes to the base station parameters.

And the focus of this method is on selection the radius of the cluster head recruitment and networks without coverage of the hole.

In this algorithm, in each round, a number between zero and one for each node is produced. If the value of a threshold value (T) is more than the specific value, that node can be considered as a cluster head.

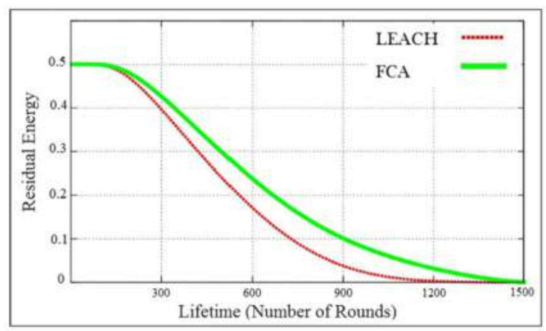
Two inputs for this fuzzy system are considered.

By the results of these simulations, we can conclude that the FCA is a stable and energy-efficient clustering algorithm for wireless sensor networks and because of the similarity with our proposed method and as well as algorithms LEACH, it Can be a good basis for a comparison with the proposed method in this article.

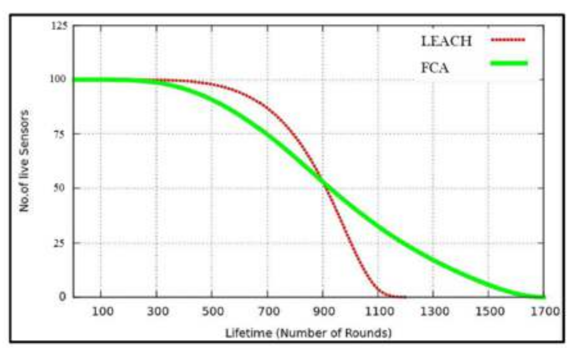
At first, we compare FCA method with LEACH algorithm and show the FCA improve over Leach algorithm in Figure (9).

In final form, Figure (10) shows the compared resulting Superiority and improvement proposed method with LEACH algorithm and FCA.

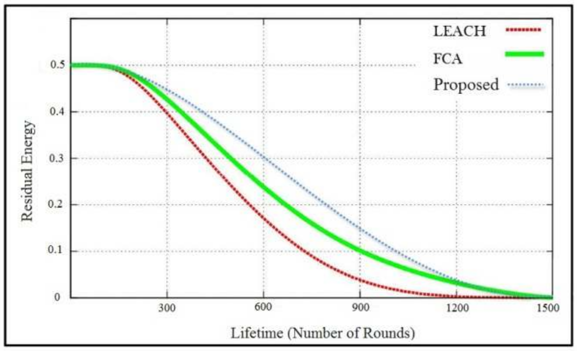
Figure (11) represents remaining energy and the numbers of live nodes are in Figure (12).



Remaining energy



Leach Vs FCA in live nodes number



Remaining energy

4-conclusion and future works:

In this paper, a new algorithm was proposed for routing in WSNs. Then a comprehensive evaluation, discussion, comparison with other methods was done. One of the drawbacks of this method is that it will not consider the privacy and security.

References:

[1] Akkaya K. and Younis M., (2005), "A survey on routing protocols for wireless sensor networks", in Proceedings of the Elsevier Ad Hoc Network Journal, pp. 325-349.

[2] Akyildiz I.F., Su.W, Sankarasubramaniam Y. and Cayircl E. (2002), “A survey on sensor networks”, in Proceedings of the IEEE Communication Magazine, Vol. 40, pp. 102-114

[3] Al-Karaki J. N. and Kamal A. E., (2004), ”Routing techniques in wireless sensor networks: a survey”. In: Proceedings of the IEEE Wireless Communications, Vol. 11, pp. 6-28.

[4] Amis A., Prakash R., Vuong T., and D. Huynh, March(2000), “Max-Min D-Cluster Formation in Wireless AdHoc Networks,” IEEE INFOCOM.

[5] Baker D.J., Ephremides A., (1981), “The architectural organization of a mobile radio network via a distributed algorithm”, IEEE Transactions on Communications, COM-29 (11), pp. 1694–1701

[6] Chan H., Perrig A., (2004), “ACE: An emergent algorithm for highly uniform cluster formation”, Proceedings of the 1st European Workshop on Sensor Networks (EWSN).

[7] Chatterjee M., Das S. K., and Turgut D., (2002), “WCA: A Weighted Clustering Algorithm for Mobile Ad Hoc Networks,” Clustering Computing, vol. 5, pp. 193–204.

[8] Demirbas M., Arora A. and Mittal V., (2004), “FLOC: A fast local clustering service for wireless sensor networks, in Proc. of Workshop on Dependability Issues in Wireless AdHoc Networks and Sensor Networks (DIWANS04), Florence, Italy.

[9] Ding P., Holliday J., Celik A., (2005), “Distributed energy efficient hierarchical clustering for wireless sensor networks”, Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS’05).

[10] Estrin D., Xu Y., Heidemann j. (2001), Geography-Informed Energy Conservation for Ad Hoc Routing. In Proceedings of the 7th Annual International Conference on Mobile Computing and Networking (Mobi-Com), Rome, Italy pp 70–84.

[11] Fan X. and Song Y., (2007), “Improvement on LEACH protocol of wireless sensor network,” IEEE Sensor Communication, pp 260–264.

[12] Godbole v.,(2012),” Performance Analysis of Clustering Protocol Using Fuzzy Logic for Wireless Sensor Network”, IAES International Journal of Artificial Intelligence (IJ-AI)Vol. 1, No. 3, ISSN: 2252-8938, pp. 103-111.

[13] Goldsmith A.J. and Wicker S.B. , (2002), “Design challenges for energy-constrained ad hoc wireless networks”, in: Proceedings of the IEEE Wireless Commun, pp. 8–27.

[14] Guang Feng Li, Taieb Z., (2007), “A ring-structured energy-efficient clustering architecture for robust communication in wireless sensor networks”, International Journal of Sensor Networks, Volume 2.

[15] Heinzelman W. R., Kulik J., and Balakrishnan H. , (2000), “Adaptive Protocols for Information Dissemination in Wireless Sensor Networks”. Proceedings of the 5th Annual International Conference on Mobile Computing and Networking, pages 174–185. ACM, Seattle, WA.

[16] Heinzelman W., chandrakasan A. and Balakrishnan H., (2000), "Energy-efficient communication protocol for wireless mi-crosensor network", in: Proceedings of the IEEE System Sciences, pp.1-10.

[17] Hill J. and Culler D. , (2002) ,“Mica: A wireless platform for deeply embedded networks”, in: Proceedings of the IEEE Micro., Vol. 22, no. 6, pp. 12-24.

[18] Huynh T. T. and Hong C. S. , (2005), "Prolonging network lifetime via intra-cluster routing in wireless sensor networks", in: Proceedings of the ICMU2005, pp. 162-167.

[19] Ilyas M. and Mahgoub I. (2005),"Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems", in: Proceedings of the CRC Press, London, Washington, D.C.

[20] Janakiram D., Venkateswarlu R. Nitin S., (2005), ”A survey on programming languages,

middleware and applications in wireless sensor networks”, in: Proceedings of the IITM-CSE-DOS-2005-04.

[21] Jiang H., Sun Y., Sun R., and Xu H., (2013), “Fuzzy-Logic-Based Energy Optimized Routing for Wireless Sensor Networks” , International Journal of Distributed Sensor Networks Volume 6, pp 1-9.

[22] Kahn J.M., Katz R.H. and Pister K.S.J., (1999), “Next century challenges: mobile networking for smart dust”, in: Proceedings of the ACM MobiCom 99, Washington, USA, pp. 271–278.

[23] Kumar S., Kumar M., Sheeba V. S., Kashwan K. R., (2012),” Cluster Based Routing Algorithm Using Dual Staged Fuzzy Logic in Wireless Sensor Networks” Journal of Information & Computational Science 9(5), pp.1281–1297

[24] Loscri V., Morabito G., and Marano S. , (2005),” A two-level hierarchy for low-energy adaptive clustering hierarchy”, Proceedings of IEEE VTC Conference 2005, Vol. 3, pp. 1809–1813.