Research Article

A Powerful Consistency Methods for Sensor Nodes Reconstruction to Enhanced the Consumed Energy of Wireless Sensor Networks

Aqeel K. Kadhim[1]
AL Neelain university, college of engineering, faculty of computer engineer, Sudan

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 23 May 2021

Abstract: Enhancing consumed energy in WSNs is prime issue, clustering is one of the main techniques that are utilizing for decreasing the energy dissipation in WSN. A Fuzzy C-Mean Clustering (FCM) algorithm is proposed as one of the important methods adopted in the clustering field. Voronoi diagram technique are contribute with FCM method to reduce the intra-clustering distance. Decision tree algorithm (DTA) is also utilized as a useful method to select high-specification sensor nodes a Custer Head (CH). This collection of algorithm and methods will has given momentum to improve network status and has an effective influence on the decreasing of consumed energy and increasing of network efficiency. The aforementioned methods, have further contributed to up growth of a new schema, which has been called Improved Voronoi Fuzzy Clustering System (IVFCS). Voronoi diagram technique that applied to split the monitoring region into a number of Voronoi position called cells, are been engaged with FCM method in order to decrees the intra-clustering communication. Decision Tree Algorithm (DTA) which is a class of supervised machine learning algorithms, that have been used professionally for the purpose of CH selecting based on the parameters of: node residual energy, distance between CH with its neighbor sensors and packet loss values. The CH electing is done in such a way that reduces the distance of communication and participate in restrict the consumed energy amount in the entire network. The unification of the above three powerful methods and their contribution towards the better choice of cluster head has led to construct an improved VFCS schema. The support of the three effective methods is to reduce consumed energy and maintained the data routing process within the network. As a result, this was effectively reflected in the continuation of network performance for a longer period if compared with well-known protocols in the field of WSNs, for example (LEACH, MOD-LEACH, SEP, Z-SEP and DEEC protocols).

Keywords: Fuzzy C-Mean, Voronoi diagram, IVFCS schema, Cluster Head and Energy consumption

1. Introduction

WSN is composed of a massive number of small, inexpensive and energy-constraint sensors that spatially distributed in order to monitor the surrounding conditions of a region of interest [1]. The main functions of sensor node are to sense surrounding area, and monitoring the environment, permitting interaction between the surrounding environment and persons or computers [2]. Process of sensing data, store the results and can communicate with restricted capabilities in power supply, storage capacity, calculation, and bandwidth. Sensor nodes will gather the sensed data from the surrounded environment, process it locally, and forward them to top level that may consists of one or more gathering points called sink or base station, the end station acts as interaction between WSN and users or internet [3].

It is a vital issue to eliminate the overall communication in WSN because the most consuming energy is the transceiver unit in sensor node. Therefore, the lifetime prolongs of the sensor node battery act as one of the important challenges in WSN [3, 4]. Because of the power-constraint of sensor nodes batteries, thus, it is important to reduce the intra-clustering communication in order to conserve the overall energy of the cluster members which reflects positively on the node lifetime and the entire energy [5][6].

Since, there is a lot of sensor nodes monitor the same area, so the transmitted sensed data to the base station or sink node may be identical. Besides that, high quantity of sensed data presents by intense sensor nods will leads to a variety of undesired topics such as network congestion, increase of processing weight on the sink node, reducing the data quality and energy consumption [7].

Clustering or grouping process define as a function of specifying a set of items to form clusters, the process of grouped nodes in one set is called "Clustering" [8]. The Voronoi object or (cell) are grouped by utilizing a Fuzzy C-Means clustering technique to eliminate the distance of data transmission for intra-clustering communication. Commonly, the algorithms of clustering or grouping items must be classified within two categories. The first is hard clustering; the second is soft or (fuzzy) clustering. The data in the hard clustering are split into separate clusters, so each data element are returns in totally one cluster. But in the other type (soft clustering), the data elements will return to greater than one cluster, also with each element a group of membership levels are correlated with.

Through what was stated above, we can conclude the following by utilizing the three powerful methods: The Voronoi diagram method will partitioned the sensed region into Voronoi cells, then the sensors network will be divided into groups of nodes or (clusters). The clustering process is construct or formation by utilizing the FCM clustering algorithm. After this process the system must select cluster head node with high parameters by utilizing DTA, then assigned member nodes to the nearest CH by computing the Euclidean distance for each node to the all elected CH.

The main objectives of the preparation stage in WSN are the formation of groups or clustering and the election of the head of the bloc. The flow chart of system model for the proposed schema is present in Figure 1.

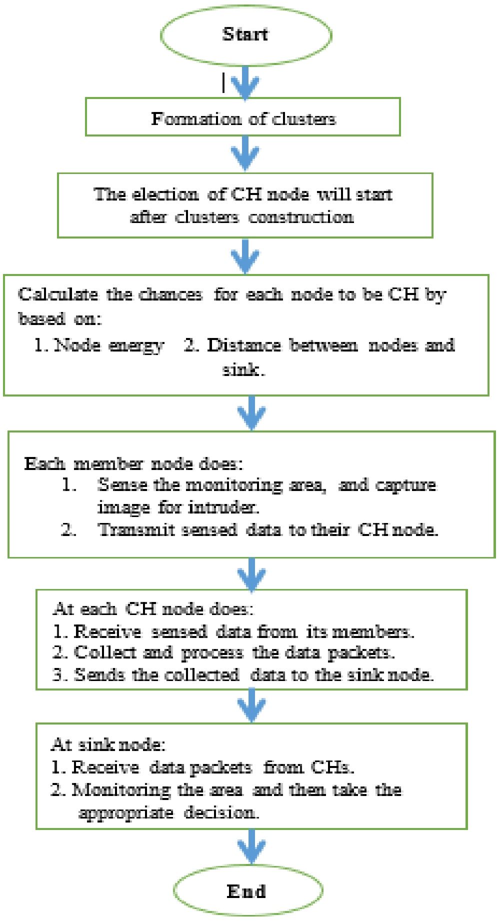


Figure 1: System model

2. The Improved Voronoi Fuzzy Clustering System (IVFCS)

The proposed schema (VFCS) will be addressed in this section in term of design, for each round in network lifetime the system consists mainly from five levels as shown in Figure 2, these levels can be summarized as follows:

- First level: Voronoi diagram construction.
- Second level: Cluster formation by using FCM and CH election through using DTA.
- Third level: First function of CHs is the collecting the sensing data from active member nodes.
- Four level: Second function of CHs is to forward the sensing data to the sink-node directly or by multi hop.
- Five level: Energy calculation of the entire network nodes for each round until all its energy will depleted.

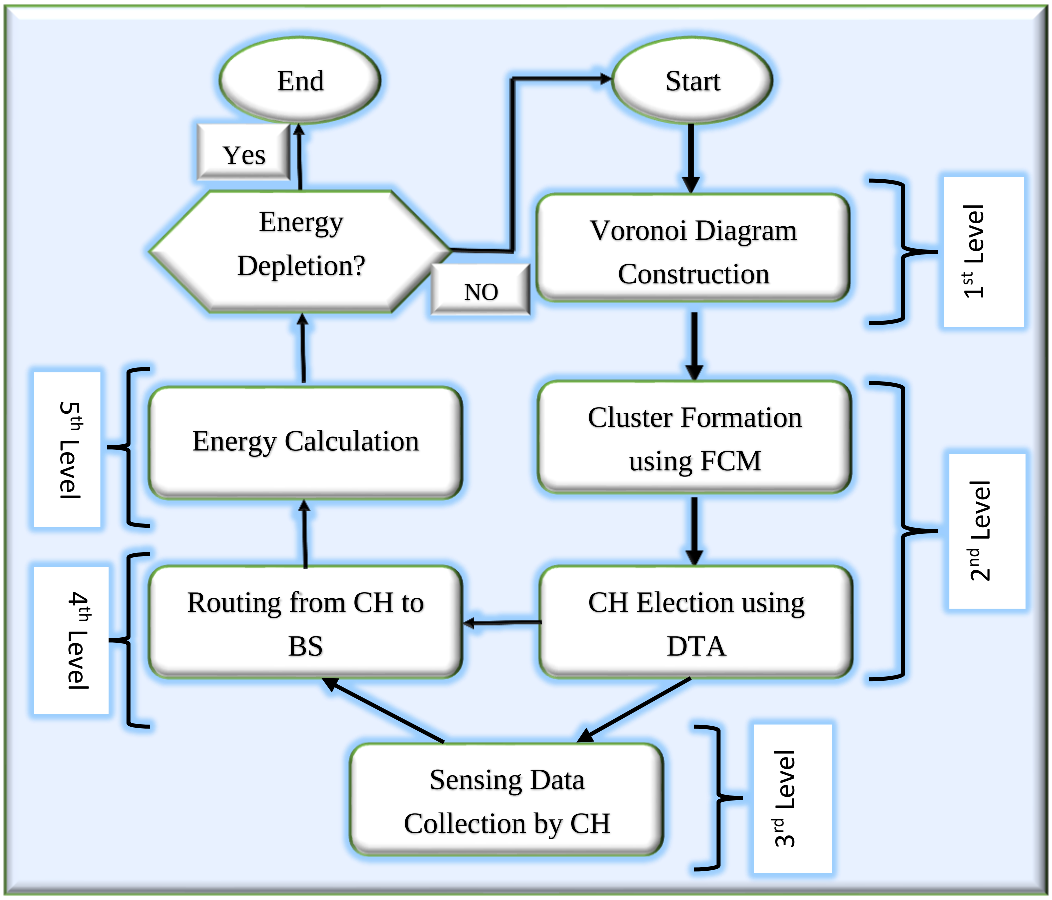


Figure 2: Steps of the proposed system

2.1 The Construction of Voronoi Diagram

Voronoi diagram is a method of spaces analysis. Suppose that *N* is define as a set of nodes that deployed in a region without any restrictions, Voronoi method will partitioned the region of interest into sub-regions, which equal to the nodes number. Every sub-region will have one node inside, these regions in the Voronoi method phase is called cells. Every cell will contain justly one site. Within the Voronoi schema attribute, each sub-region consists of the position or area which are closest to the node in which it is located.

In the improved algorithm, all sensor nodes are supposed to be fixed. Therefore, the position of sensor node can be calculated by the coordinates of ***x*** and ***y***. So, for any node:

$p_i = s = (x_i, y_i)$ (where p_i is the sensor ***s*** position), and the function to calculate distance in Voronoi diagram must be computed by equation 1 [9]:

$$d = \sqrt{(x_s - x_r)^2 + (y_s - y_r)^2} \qquad (1)$$

Where:

r**:** represent all neighboring nodes set.

Let $P = \{p_1, p_2, \ldots, p_n\}$ **as** a group of separate points (positions) in the interested plane or area. The Voronoi diagram will portioned this area into ***n*** Voronoi cells, so every cell will have exactly one position. A randomly point ***(x, y)*** in a cell will return to the position, with a coordinate of (Xp_i, Yp_i) if the Euclidean distance that computed from point ***(x, y)*** to any other point is more than the distance from point ***(x, y)*** to position *pi*, with the condition of (all p_j with $j \neq i$, $1 \leq i$, $j \leq n$.), as explained in equation 2. [10].

$$(d = \sqrt{(x - X_{pi})^2 + (y - Y_{pi})^2)} < (d = \sqrt{(x - X_{pj})^2 + (y - Y_{pj})^2)} \ldots\ldots\ldots\ldots (2)$$

$V(p_i)$ is the Voronoi area of position p_i, which may be also referred to as V_i. Whole Voronoi areas that place in a normal Voronoi will be linked and convex. The outlines of every cell can be collected from straight lines and section create convex polygons, and will be defined by the vertical *bi*-sectors of sections that connect every pairs of positions. It is inessential to compute distance to every position to locate which site is closest to a specific object within Voronoi diagram.

2.2 Cluster Formation using FCM

The clustering process is defined as a method of determining a working group of elements with similar properties to form cluster. The Voronoi object or (cell) are grouped by utilizing a Fuzzy C-Means technique to eliminate the distance of data transmission for intra-clustering communication.

The main objectives in WSNs are the formation of groups or clustering, and the election of the head of the bloc. After the Voronoi diagram method will partitioned the sensed region into Voronoi cells, then the sensor network will be divided into groups of nodes or (clusters). Therefore, the FCM clustering algorithm is one of the powerful way to construct or formation these sensor nodes. After the clustering process the system must select cluster head node with high parameters, then assigned member nodes to the nearest CH by computing the Euclidean distance for each node to the all elected CH.

2.3 Cluster Head Election using DTA

One of the effective algorithms that were used in this study is the Decision Tree Algorithm (DTA) which falls under the category of supervised machine learning algorithms for identifying Cluster Head (CH). DTA was used in the improved algorithm (VFCS) to select the header node within the class, this process mainly enhances data collection and reduce the distance of data transfer which finally conserve the energy consumption from entire network that effectively extends the network life span. Within this algorithm a suitable cluster head (CH) will be elected for each cluster. There are three main parameters involved in the election process, (i) the residual energy, (ii) distance between elected CH and its neighbor sensors and (iii) packet loss values. The scheme of selecting the cluster head is done in such a way that reduces the intra-cluster communication distance which then conserve node energy. Simulation result shows that smart CH selection improves the performance in terms of energy consumption rate and network life time.

Furthermore, the sensing data that gathered from active sensor members of each effective cluster is then forwarding by CH to sink node (by single hop or multi-hops). This process will depend on threshold value for the sensing data, (threshold value means that the received sensed data value must have a significant difference from the stored data value). This will lead to prolong the lifetime of network, decrease the data traffic congestion in network and also decrease the overhead messages that may occur in the buffer of sink node.

The node that is nearest to the center of cluster can be selected as CH, this process is only for the first round (because all sensors initially have same energy). For the next rounds the CH election will depending on the parameters of residual energy and distance between node and cluster center.

2.4 The Set-up Phase

One of the improved VFCS schema functions is group the sensor nodes in clusters and then gathering the sensed data from active sensor nodes. Based on the distance of every node from center of cluster and node residual energy as a significant parameter for CH selection.

The flowchart of the set-up phase steps that explain the steps of CH election for the improve VFCS schema can be shown in Figure 3.

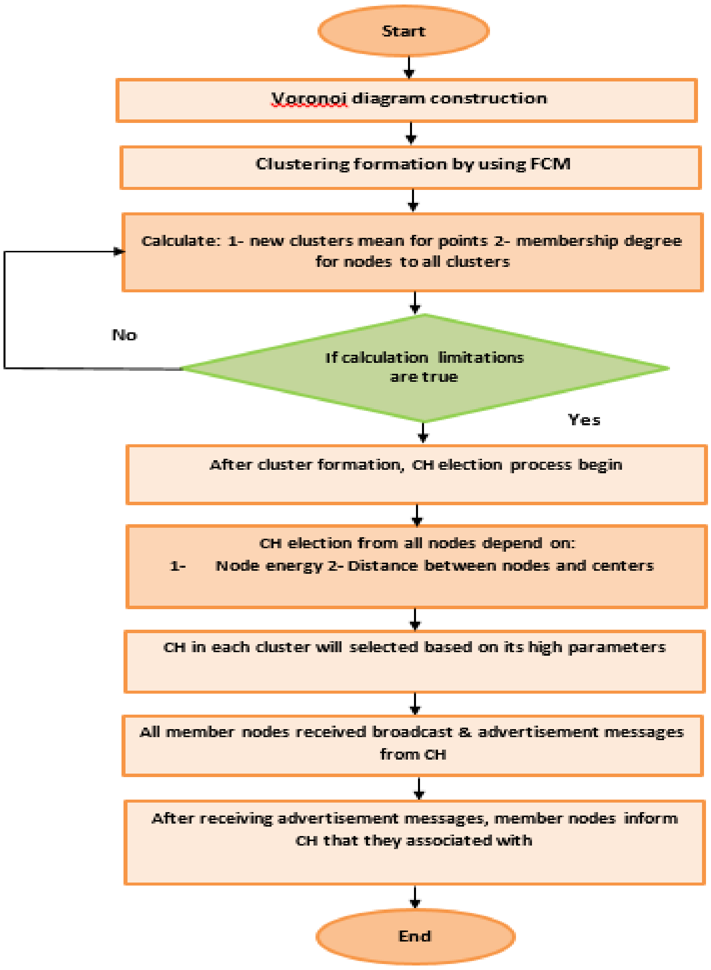


Figure 3: Set-up phase based on energy of nodes and distance between them

2.5 The Routing or Steady-State Phase

Sending data between node members and CHs can be started as soon as clusters are build and CH are elected. The sensed data transmitting process, will start from active nodes within the monitoring area to communicate with sink node. This connection does not occur directly, the active node is connected to belonging CH, and all event driven headers transfer the data to the CHs at top level nearby the main station and then the processed data will convey to sink node.

In routing phase, the sensed data in wireless sensor network, will be transmits from each active sensor node after processing to the belonging CH. Then the CH forward the gathering sensing data to the sink node or base station for a specific period of time.

The flowchart of the steady state phase steps depending on node energy and distance between normal nodes with its cluster head of the IVFCS can be shown in Figure 4.

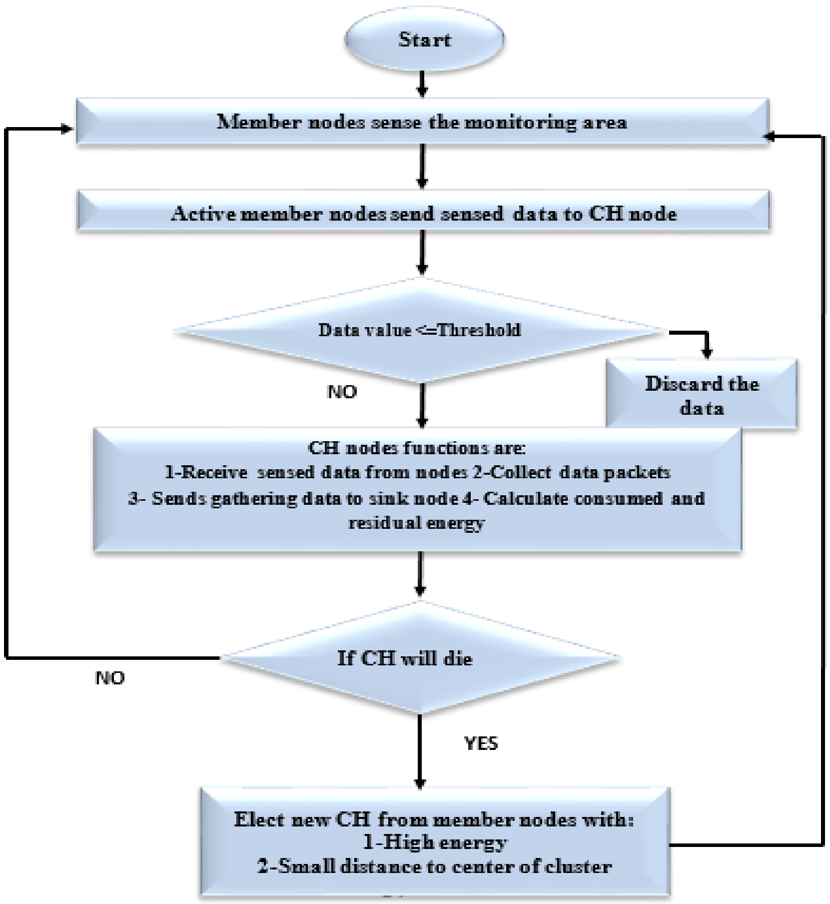


Figure 4: Data transmission based on node energy and distance

3. Simulation Parameters

A base station or sink node location is at (50, 100) Cartesian coordinates, the other simulation parameters value that be used for proposed system is mentioned in Table 1.

Table 1: Network Parameters and Scenarios

Parameter	Value	Description
A	*100 x 100*	Network Area *(m x m)*
N	*100*	Number of Total Nodes
SN	*50 x 100*	Sink Node Location *(m x m)*
M	*4000*	Data Packet Size in byte
d_o	*87 m*	Threshold Distance
IE	*2J*	Initial Energy in *Joul*
E_{Tx}	*50 nJ/bit/signal*	Energy Consumption of Data Transmitting
E_{Rx}	*50 nJ/bit/signal*	Energy Consumption of Data Receiving
E_{elec}	*50 nJ/bit*	Transmitter and Receiver
E_{fs}	$10\ pJ/bit/m^2$	Transmitting Amplifier Energy Consumption when $d < do$
E_{mp}	$0.0013\ pJ/bit/m^4$	Transmitting Amplifier Energy Consumption when $d \geq do$
E_{DA}	*5 nJ/bit/signal*	Energy Consumption in Data Aggregation

E_{sleep}	*50 pJ/minute*	Consumed Energy of Sleep Mode
E_{active}	*5 μJ/minute*	Consumed Energy of Active Mode

4. Performance Evaluation Metrics for Improved VFCS

To evaluate the improved VFCS performance in wireless sensor network, several performance matrices must be considered and calculated. The following is two of these important performance metrics:

- **Network Lifetime**

The lifetime of network is the time period between the initialization of network and the last live nodes expiry in the network, or the time duration which allows nodes to forward the maximum amount of data to the sink node.

- **Rate of Energy Consumption *(Ea)***

The rate or average consumed energy is the average variation between the initial energy level and the current energy level that be remaining in every node for every round. Equation 3 present the calculation of the average consumed energy for the entire network.

$$E_a = \frac{\sum_{K=1}^{N}(E_{ik} - E_{ck})}{N} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where:

E_{ik} = is the initial level of node energy.

E_{ck} = is the current level of node energy.

N = the nodes quantity in the simulation.

5. Simulation and practical results

In order to know the effectiveness of the system that was installed by depending on the above powerful methods (Voronoi diagram, FCM and DTA), and to investigate the proficiency of these methods to support the reducing of the consumed energy and data routing continuity from active sensors to the sink node. The following simulation was done (for the proposed network environment that have been presented in section 3), between the improved VFCS schema and the well-known routing protocols (LEATCH, mod-LEATCH, SEP, Z-SEP and DEEC). The simulation is performed by using Graphical User Interface GUI for Matlab program. The proposed WSN are accomplished with total number of n-network nodes that is supposed to be fixed and deployed randomly in the monitoring area with 100 x 100 m. The simulation parameters and scenarios of network for the proposed schema are listed in Table 1.

After receiving the above parameters, the improved VFCS will performs some statistics and explain network response through generate graphics as a results of system implementation, that illustrate the distribution/clustering of sensors on the proposed sensed area, and CHs selection by utilizing Voronoi diagram, fuzzy C-Mean clustering algorithm and DTA.

5.1 Experimental Model

At the beginning of the simulation, the schema need to input the nodes number of the proposed network, as experimental example let sensor nodes equal to 100. Voronoi diagram is applied for the elected number of sensor nodes, and distribute them to cover whole sensed area as shown in Figure 5. Then number of clusters in the network must be entered also, these clusters have been selected to partition the Voronoi cells between clusters by put in application the FCM algorithms. The FCM clustering algorithm will repetitively move the cluster centers to the correct location. The DTA method is elected the appropriate CHs from each cluster depends on some parameters. Figure 6 presents the location of the final centers if we choose the clusters number equal to five clusters as a practical example.

In order to uniform creation of partitioning clusters, nodes are categorized into clusters depending on the maximum membership level in every cluster in first round, *the technique will select the node that is close to cluster centers as cluster header*.

Clustering construction and CH election consider as a prime aim of set-up phase. Afterward, apply the FCM algorithm as shown in Figure 6, we could obtain five clusters (if the number of cluster is entered as 5), also by utilizing DTA method we obtained five cluster heads which are mainly chosen based on the distance calculation between their positions and the center of cluster, all these considerations are only for first round. However, the calculations for the next rounds include the parameter of the residual energy in each node.

Figure 7 present the locations of the five clusters, and the distance for each node in the cluster to the cluster center. This figure explains in detail the position of all cluster nodes with reference to centers of clusters, all calculation is done through utilizing FCM method.

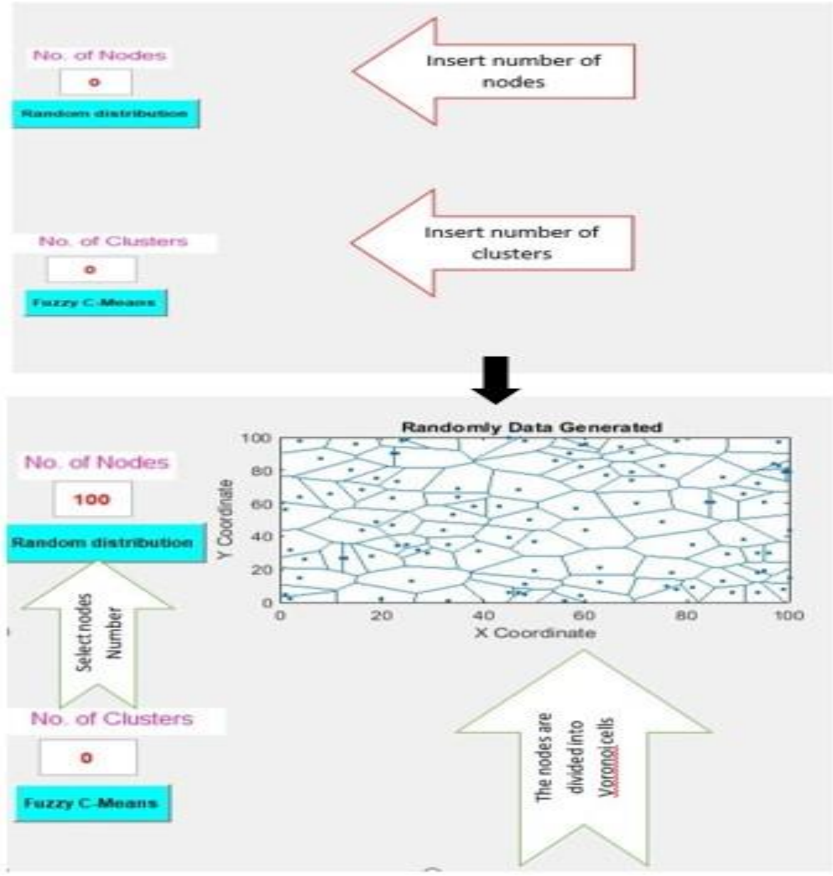


Figure 5: The nodes deployment after utilizing Voronoi method

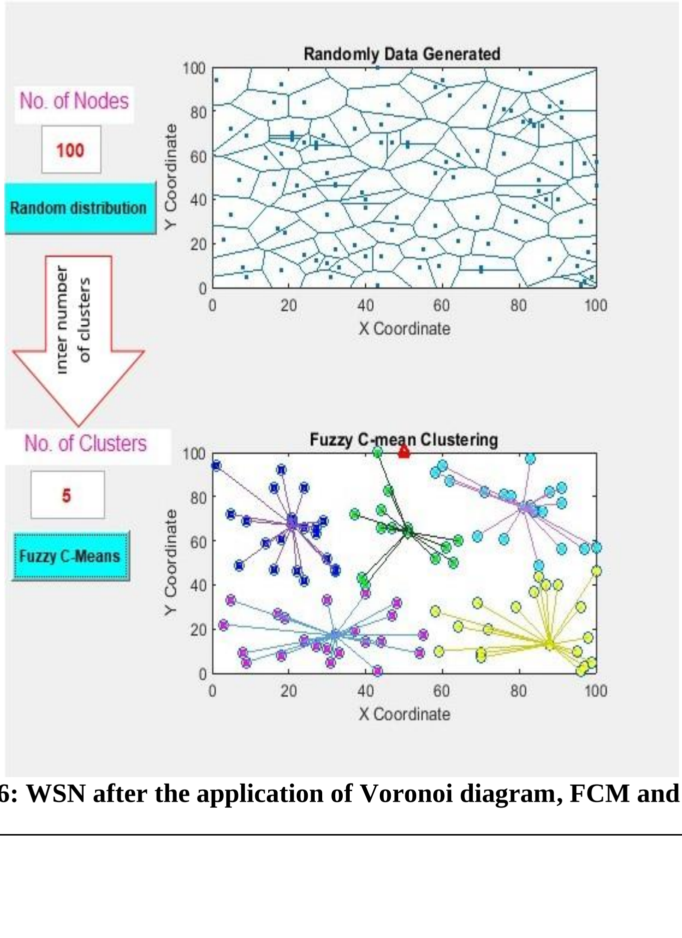
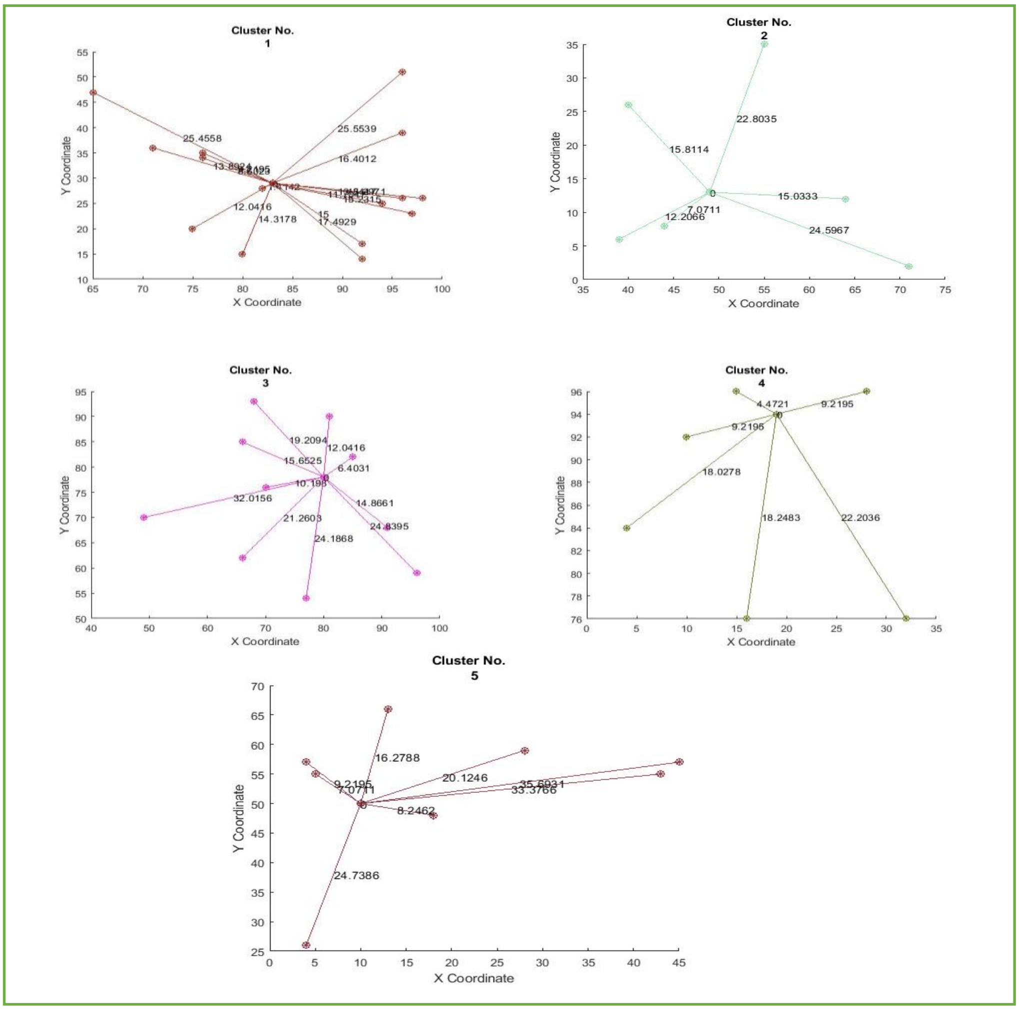


Figure 6: WSN after the application of Voronoi diagram, FCM and DTA methods



5.2 Evaluation Metrics

5.2.1 Network Lifetime

Network lifetime is the period of time that permits sensors nodes to transmit the most amounts of sensed data to the belonging CHs and then forward the data to sink node or base station directly or by multi-hop.

The performance of the IVFCS schema can be evaluated by make a comparison of network lifetime for the improved VFCS and well-known protocols like: (LEACH, Mod-Leach and DEEC) will be done. The comparison of the improved VFACS is take place in two cases (with and without threshold). Simulation results is achieved by implementing the following factors: live nodes number with the rounds number (with and without threshold) value, during the process of routing until the life of the last node in the WSN will be end, as explained in Figure 8. For more explanation and higher accuracy, a single comparison was made between the IVFCS schema (with and without threshold) and DEEC protocol as shows in Figure 9.

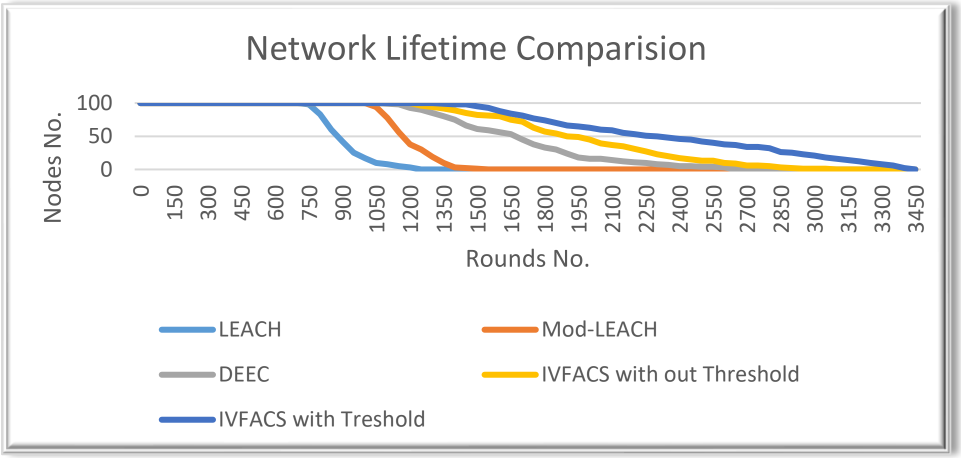


Figure 8: Network lifetime comparision-1

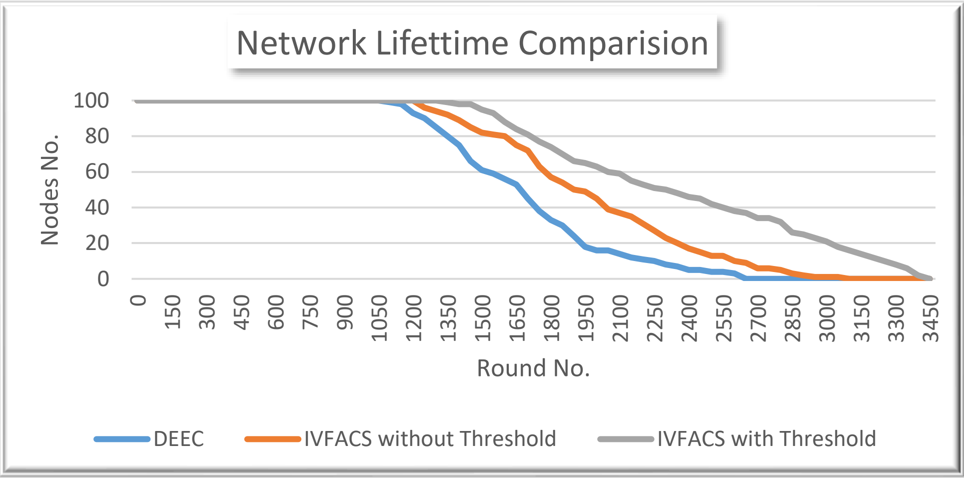


Figure 9: Network lifetime comparision-2

The stability period of improved VFCS is better than other selected protocols. From Figure 8 and Figure 9 we can clarify the following details:

1- First node will die in LEACH protocol within round number which equal to 750 and the last node will die within round number 1250.

2- First node will die in Mod-LEACH protocol within round number which equal to 1002 and the last node will die within round number 1587.

3- First node will die in DEEC protocol within round number which equal to 1100 and the last node will die within round number 2650.

4- In the improved VFCS (without threshold), the first node will die at round number 1201 but the last node will die at round number which equal to 3100.

5- In the improved VFCS (with threshold), the first node will die at round number 1349 but the last node will die at round number which equal to 3450.

An extra comparison study is done between IVFCS schema and (LEACH, SEP, Z-SEP and DEEC) protocols. The comparison of the improved VFCS is take place only without threshold.

Simulation results is accomplished by implementing the following parameters: a live nodes number against the rounds number value, for the five protocols as explained in Figure 10. A dead nodes number against the rounds number for the five protocols is explained in Figure 11. In other context the live node and dead node states will express about the network lifetime.

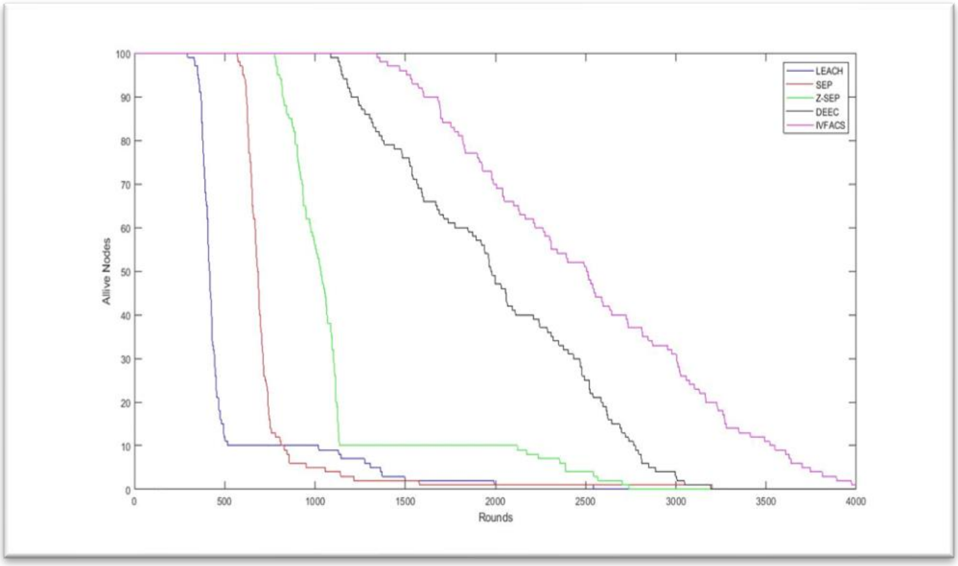


Figure 10: Live nodes against round number for the 5 protocols

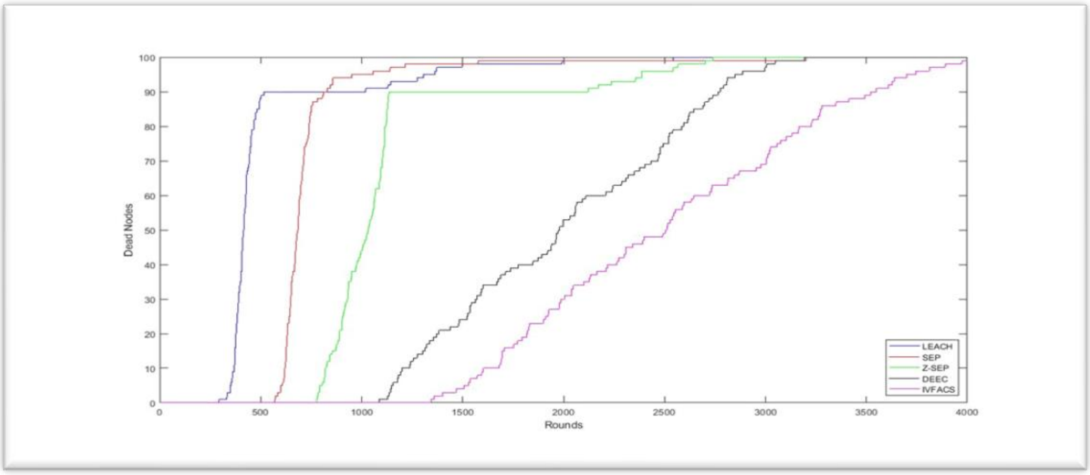


Figure 11: Dead nodes against round number for the 5 protocols

5.2.2 Residual Energy Computation

The comparison of the residual energy for the entire members of WSN in each round, between the IVFCS schema by utilizing the two cases (with and without threshold) and DEEC protocol, will be seen in Figure 12.

The experimental results are done with the variables of 100 nodes and maximum rounds of about 4500. The graph shows the residual energy in the entire network at each round for the two types of systems. We can show from the figure bellow that the residual energy for the improved VFCS with threshold value will be more than the residual energy with-out threshold. But the remaining energy at each round of the improved VFCS without threshold is better than the DEEC protocol.

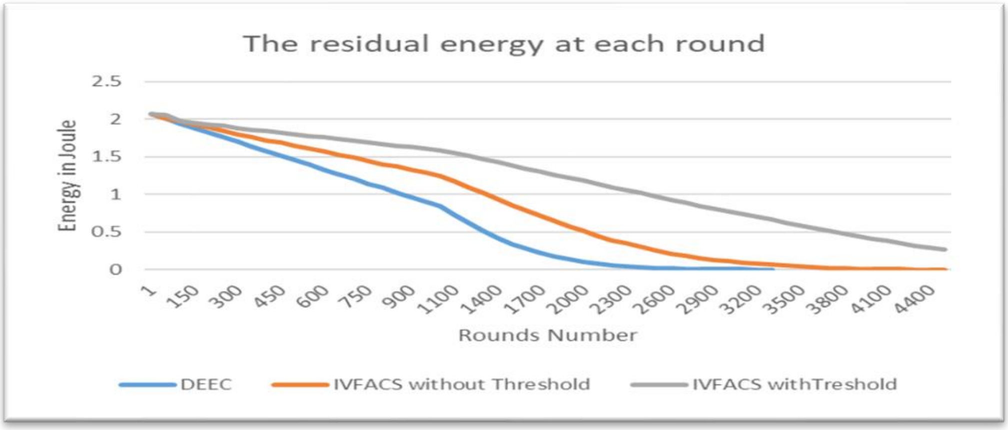


Figure 12: Residual energy for different methods

An additional comparative study of the consumed energy volume from all nodes in WSN per round between the IVFAC schema without threshold and LEACH, SEP, Z-SEP and DEEC protocols, will be shown in Figure 13. The experimental results are done with the following variables (number of nodes equal to 100 and maximum rounds of about 4000). The graph will show the residual energy for all nodes in network at each round for the five types of protocols.

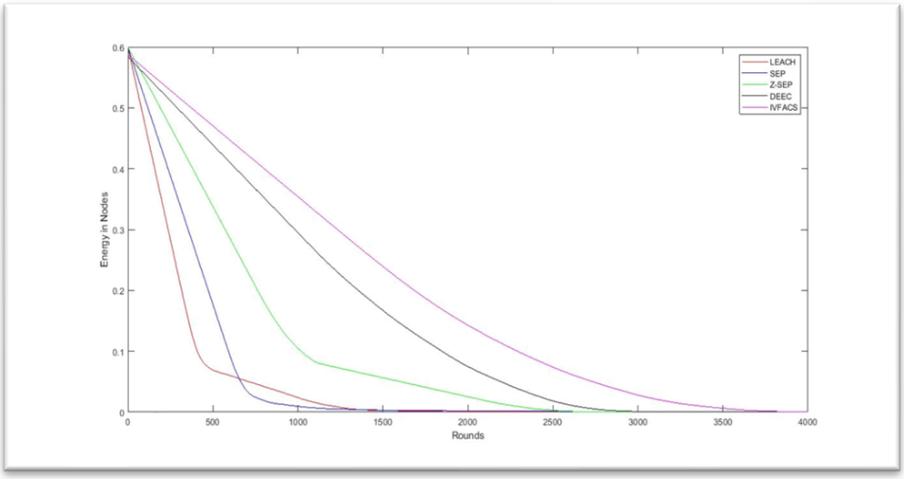


Figure 13: Consumed energy against round number for the 5 protocols

6. Conclusion

The process of analyzing and understanding the results obtained through the methods that have been reviewed in this study. Will lead to the conclusion of this research. We have focused on the design of robust system to manage sensors node distributing/clustering and CHs selection, in order to reducing intra-clustering communication and eliminate power consumption for prolonging the WSN lifetime. In this paper, an improved VFCS schema is presented, three effective methods (Voronoi diagram, FCM and DTA) are utilized, to support and maintain the data routing process within the network. Through the practical results obtained from the use of these powerful methods and their vital effect in prolong the life of the network when compared with well-known protocols, we can conclude the followings:

The IVFCS protocol also present improvements in term of network lifetime, as compared with well-known (LEACH, Mod-LEACH and DEEC) protocols. When the improved VFCS is applied with threshold value, the network lifetime will be extended than if we using improved VFCS protocol without threshold value.

Also, for average consumed energy the performance of proposed system is better than LEACH protocol. The practical results present that the IVFCS schema has improved stability of the network in a superior way. An extra comparison between IVFCS and a set of well-known protocols like (LEACH, SEP, Z-SEP and DEEC) protocols, in terms of nodes residual energy and network lifetime will present positively reflect on consumed energy and the longevity of the network. Also the residual energy for the improved VFCS (without threshold) is better as compared with DEEC protocol, this will lead that the proposed system is scalable and load balancing.

Refrences

1. Chand, K. K., Bharati, P. V., and Ramanjaneyulu, B. S., “Optimized energy efficient routing protocol for life-time improvement in wireless sensor networks”, In *Advances in Engineering, Science and Management (ICAESM), International Conference on* (pp. 345-349), IEEE. 2012.
2. Ridha SOUA; “Wireless Sensor Networks in Industrial Environment”; Energy Efficiency, Delay and Scalability”; Phd. Thesis; February 25, 2014.
3. Idrees, A. K., Deschinkel, K., Salomon, M., and Couturier, R., “Distributed lifetime coverage optimization protocol in wireless sensor networks”, *The Journal of Supercomputing*, Vol. 71, No. 12, pp.4578-4593. 2015.
4. Abdelaal, M., Theel, O., Kuka, C., Zhang, P., Gao, Y., Bashlovkina, V., and Fränzle, M., “Improving energy efficiency in QoS-constrained wireless sensor networks”, *International Journal of Distributed Sensor Networks*, Vol. 12, No. 5, pp.1576038. 2016.
5. Misra, S., Zhang, I., and Misra, S. C. (Eds.), “Guide to wireless sensor networks”, Computer Communications and Networks; ISBN 978-1-84882-218-4 book; Springer Science & Business Media. 2009.
6. Aqeel K. Kadhim; “An Efficient Technique to Improve Energy Exhausting in Intra-Clustering Communication for WSN”; Al-Mustansria University, journal of college education; Vol. 3, pp 91-108, 2019
7. Wang, C., Ma, H., He, Y., and Xiong, S., “Adaptive approximate data collection for wireless sensor networks”, *IEEE Transactions on Parallel and Distributed Systems*, Vol. *23*, No. 6, pp.1004-1016. 2012.
8. A. Shahraki, A. Taherkordi, Ø. Haugen et al.; “Clustering objectives in wireless sensor networks: A survey and research direction analysis”; Computer Networks Volume 180, 24 October 2020, 107376; Published by Elsevier B.V; https://doi.org/10.1016/j.comnet.2020.107376
9. Zhai, X., and Vladimirova, T., “Data aggregation in wireless sensor networks for lunar exploration”, In *Emerging Security Technologies (EST), 2015 Sixth International Conference on* (pp. 30-37), IEEE. 2015.
10. Rumpa Mukherjee,Arindom Mukherjee ,” A Survey on Different Approaches for Energy conservation in Wireless Sensor Networks” , International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970), Volume-3 Number-1 Issue-8 March-2013.