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An Improved LEACH algorithm based on Fuzzy C-means algorithm and Distributed Cluster Head Selection mechanism

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ABSTRACT

The beneficial capability of Wireless Sensor Networks (WSNs) to check numerous types of environmental settings via detection mechanisms on the physical state of matters discovered through researches, has attracted great interest in many quarters. Significant necessities in a majority of applications related to sensor networks are the extensive duration of network lifespan. Towards the fulfillment of such requirements, the clustering sensor nodes is an efficient method for the purpose of achieving these ends. The fundamental goal of WSN routing protocol are in maintaining the equilibrium of network energy usage, and in stretching the total network lifespan. The most famous protocol that utilized clustering technique is Low Energy Adaptive Clustering Hierarchy (LEACH). In LEACH algorithm, the random manner is used to select specific nodes as a cluster heads. In addition, the resulting clusters suffer from an imbalance in cluster size. In this study, the LEACH issues are solved by utilizing Fuzzy C-means algorithm (FCM) to form balanced clusters,which is followed by the selection of the cluster head in each cluster according to the energy of nodes and distance to the cluster centroid. The comparison of therecommended algorithm with LEACH algorithm is conducted, in relations to energy consumption and network lifetime. The result showed that our proposed algorithm has further advantage over LEACH.

Keywords:Wireless sensor networks, Clustering technique, LEACH algorithm, FCM algorithm.

1 INTRODUCTION

The emerging technology of Wireless Sensor Network (WSN) possesses an expansive range of applications. They comprise ofthe safeguarding of infrastructure, sensing used in industries and their diagnostics, the surveillance on warzone and the environment, the climatic control system at the micro level of buildings, the detecting capabilities of assaults in biological or nuclear form, the computation system that are contextual such as smart home systems and sensitive response to thesurroundings[1][2][3]. These networks normally constitute a luge expanse of sensory nodes that have limitations in terms of resources, and are often disseminated at random or in a uniform mannerat the zone to be sensed, for the monitoring of the physical statelike thedampness and thermic conditionof that zone. The major WSN elements consists of the sensor nodes and a Base Station (BS), or known as a sink, in which the compilation of theincidents being tracked and checked is conducted[1].

Typically, the BS does not experience limitations in resources, however there is a possibility that it is positioned remote to the site being monitored. The capability to monitor the environmental and physical conditions through sensing method is possessed by the sensor nodes.In performing their duties, theminute sensors that are limited in their resources, requires them to engage in corporation. The sensor's compiled data are transmitted to a centralized position at BSthat is linked to the internet. The essential WSNs benefitlies in their ability to function in hostileconditions, and cases of the middle-man control and tracking negotiations are inadequate and hazardous[4][5]. There is choice of whether the wireless sensors are

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disseminated through manual means in predefinedsites, or disseminated atrandom into the surroundingsthrough quite rampant methodswhich are reliant upon implementation necessities. Numerousimplementations involve a huge amount(spanning from hundreds to thousands) of sensors being disseminated to the targetted area, according to the expanse of the zone and the brief sensors lifespan.

The ultimate significant WSNs important issueentails the use of power due to the fact that the sensors possess limited resource in energy, for example batteries, thatirreplaceable. This is becausethey arenormally disseminated in places that cannot be accessedlike habitations in nature, savage zones, and areas that are prone to earthquake. Hence, it is extremely necessary for the formation of power effectiveprocedure a power addressing such types networks, for maintenance purposes on the functioning and lifespan extension. The Wireless Sensor Network acquired a huge portion of the traditional networks characteristics. Nevertheless, the specificcharacteristics of the mentioned network accumulated further restrictions that requires to be managedlike the power usage.As an exemplar, there are no problems with regards to energy in traditional networks, whereas in WSNs every individual node is provided with a miniature battery which possessesrestrictedfunctioning duration, that are dependentupon the treatment and the transmissions that the node executed the entire of its lifespan. Furthermore, there is an absence in computing and memory in the nodes, which arerequiredduring theapplication of a complicated routing protocol.

Numerous applications employed WSNslike relief applications such as used in disaster and hazard incidents, environmental control and biodiversity mapping, target-oriented field imaging, climate changes tracking, tactical monitoring, institutionaladministration, medical and wellbeing care, and others[6][7][8]. Generally, every WSNs applications is categorized into 3categories surveillance applications, data compilation application, and monitoring of entities applications. Wireless Sensor Networks possess commonality inissues with ad hoc networks. Nonetheless, emerging problems have surfaced due to the resource limitations faced by these devices, in addition to the restricted memory and storage volume, constrained rate of processing,restricted transmission scope, and restrictedprovision of energy. Several problems encounteredby Wireless Sensor Networkare dynamic network topology, the overlapping of areas under sensor, wireless communications medium and short network lifespan[6][9]. In addressing the aforementioned problems, it is imperative to construct a sensor network whichuses routing protocols that are energy sensitive with multi-hop communication paradigm, and autonomous reconfiguration and autonomous organization capabilities.

Clustering technique is an effectivetechniquein the construction ofbeneficial and adaptable WSNsprotocols. Itreduces overflowin communications, which resulted in energy reduction and flowdisturbances. Clustering is a technique found in numerous applications for placing the nodes in groups, that are positionedmutually in close proximity, to benefit from the pertinent data, and to eliminateunnecessary data. Hence,clustering-based routing protocol technique is amongthe optimal significanttechniques in reducing WSNs energy usage[10][11]. The Low-Energy Adaptive Clustering Hierarchy (LEACH) entails a conventional wireless sensor networks clustering routing [12]. Nevertheless, the choice of cluster-head in LEACH protocol is lacking interms of maintaining the equilibrium in the energy usage ofthe entire network, leading to thepremature exhaustion of energy in low energy nodes, and decrease in thelifespan of the network. The current studyengages in an analysis on the efficiency of LEACH protocol in the choosing of cluster-head, and recommends an enhanced energy balanced clustering algorithm. Certain specific characteristics of the LEACH protocol found in [13]consists of:

- The cluster synchronization and control, is kept at the local level in theinstallation stage
- The Cluster Headpart undergoes a rotational and randomization process for the disseminationof needed energy for the nodes in the network.

- Fortotal quantity of data transference reduction, where localized compression methods are utilized in the Cluster Head (CH).
- the appropriateness of LEACH for homogeneous networks.

In this study, the LEACH algorithm is improved by utilizing fuzzy C-means (FCM) algorithm to form balanced clusters, where the cluster head is then chosen in individual cluster according to energy of nodes and distance to the cluster centroid by distributed mechanism. In clustering algorithm, the maintenance of cluster energy equilibrium is the main objective, and in conclusion;extend networklifespan and coverage.

II. LITRATURE SURVEY

Wireless Sensor Networks entail sensor nodes clusters which are able to engage in mutual communications through wireless connections. Every individual cluster is manifested by a node as cluster head, for the purpose of maintaininga straightforward communication with the sink, in addition of communicationsthe rest of the Cluster Heads. Typically, thequalified CH selection is a pertinent and significant concern on the utilized WSNs achievements. Prevalently in the past years, there have been varying algorithms in solving WSNs clustering by various researchers. LEACH Protocol is the inaugural and the renownclustering protocol in Wireless Sensor Networks wherethe clustering is disseminated. Using LEACH Protocol, the Cluster Heads are chosen in a random manner from the nodes,signifying that the nodes in entirety possess equal opportunity to be chosen as Cluster Head, and individual node initiate communications with the Base Stationthrough the Cluster Heads[12] (Heinzelman et al., 2000).

There are a lot of studies are developed based on LEACH, such as Mahmood et al. [14]recommendedmodified LEACH (MODLEACH) algorithm through the extensionof the fundamental LEACH algorithm for Wireless Sensor Networks to heighten the throughput and network lifespan. The notions of effective cluster head replacement scheme and dual transmitting power levels were presented in MODLEACH algorithm. In their work,Wang and Yong [15]had recommended cluster head choicethrough pseudo cluster concept. In addition, the mechanisms of Load Monitor and Load Leisure techniques wasutilized for the maintenance of the equilibrium of the load and to stabilize the network topology. Outcomes from simulation result indicate thatLEACH-P Protocol enables and heightens the effective energyusage, extends network lifespan and adjusts the load on the network. In their research, Azim et al. [16]recommended the use of nodes relay-based fixed LEACH algorithm. The conservation of the WSN nodes battery power through the utilization of LEACH alongside its varying variantsthat possess clustering methods to keep the energy consumption to a minimum by maintaining of the numerous nodes in sleep mode,however maintaining the provision of favourableQuality of Service (QOS). Further to that, EEE-LEACH or Energy Efficient Extended LEACH [17]entail a method which utilizes multilevel clustering methodfor the enhancementof energy effectivenessthrough the reduction of its radio communication range. In addition, Bhadeshiya et al. [18]suggested an algorithm forchoosing fourpercent or five percent of fixed quantity of clusters in WSN according to the residual energy. Moreover, Wu and Wang [19]made a comparison on the LEACH and LEACH-C achievements. LEACH-C (centralized LEACH) involving a LEACH-based central control clustering algorithm. The stablecondition utilized in LEACH-C is the same as in theinstallationstage of LEACH.Additionally, in Leach-C every individual node transmits the datapertaining the presentposition and the energy level to the sink.In their research,Farooq et al. [20]introduced the Multi-Hop Routing with Low Energy Adaptive Clustering Hierarchy (MR-LEACH) protocol for Wireless Sensor Network. In MR-LEACH the entire network coverage area is segregated into varying clusters layers. Based on work by Sharma et al. [21]they recommended thebest possible chain-based protocol. Strictly at the termination of every individual round that the entire nodes transfer the information to the sink,consequentlydecrease the power usage due to data transference per course turn. Furthermore, Tan et al. [22]presented the Wireless Home Sensor Networks (WHSN) that possess plug-in nodes.

Plug-in nodes do not utilize energy, and the modified form of protocols like LEACH, SPIN and DD in WHSN are termed as LEACH-Pi, SPIN-Pi and DD-Pi. This is achievedthrough the alteration of the voting, evaluating, and routing methodthat immenselyimproved their achievements, lifespan, network response time, and energy usage. Furthermore,Mu Tong et al. [23]recommended the use of LEACH-B algorithm in orderto maintain the amount of CHsaccording to the sensor nodes' residual energy.From the work of Qian Liao [24]suggested that theselection of Cluster Heads that founded on the basis ofthe residual energy, and nodes positioningdata,in addition to the optimization of the parameters for the assignment of the electing CH. It should be noted that the construction of the Cost Function is for theenhancement of the perfectCH choice. Outcomes from simulation substantiated that L- LEACH keeps the equilibrium of the node energy in a more superior way as compared to that of LEACH. In another study by Iqbal et al. [25]recommended a static clustering known as Advanced Low-Energy Adaptive Clustering Hierarchy (Ad- LEACH) for heterogeneous WSN routing. s The segregation of the network in totality into minute and static clusters is executed, where the CH is chosenthrough theutilization of Distributed Energy-Efficient Clustering (DEEC). On another note, Wang and Zhu et al. [26]recommended LEACH-R routing for the enhancementof the making of CH choiceis carried out via the choosing of relaying node. The nodes' residual energy, in addition to the proximal length fromthe Base Station are utilized to ascertain the distance of the relaying node from the Cluster Heads and the node that was chosento be the relay node between the BS and additional ClusterHeads.In their research, Bouyer and et al. [11]recommendeda freshmethod for reducing energy in WSNsusing Hybrid LEACH protocol and fuzzy C-means algorithm. In their study, they introduced a clustering protocol based on anincorporationof fuzzy C-means (FCM) algorithm and LEACH algorithm.

At any time in the clustering hybrid protocol, everynode is based on fuzzy C-means, andare founded on three essentialelements which are description of energy, the dissemination, in addition to the centralized localization as compared to the neighbors in their participation in the procedures of selectingthe Cluster Heads. Every single node will make a status comparison with the neighboring nodes, and in instances that the its energy surpasses that ofits neighbouring node, it will presents itself as the Cluster Head node. Firstly, in a hybrid protocol, theassignment of the Cluster Heads are according to the degree of their energy, in addition to theirremoteness from the nodes, where the clustering process are then initiated through thelinking of the nodes to the most proximate cluster.The current study contains ourimproved LEACH protocol through the utilization of the FCM for the formation of the clusters, and the introductionof a distributed algorithm to select the Cluster Headon the basis of thenode's residual energy and theremoteness from the cluster centroid. In the next section, the proposed algorithm is briefly explained.

III. PROPOSED WORK

In LEACH algorithm, the random manner is used to select specific nodes as Cluster Heads. However, occasionally,the selected CH does not have sufficient energy to communicate and convey the sensing data to the BS. In addition, the selected CHs have responsibility for the formation of the clusters by broadcasting advertising messages for the cluster to join other nodes. Due to random selection and lack of equal distribution of heads over the monitoring area, the resulting clusters suffer from an imbalance in cluster size. Furthermore, re-selecting the CH and re-formation of the clusters in each round leads to make the network not stable. Thus, the recommended algorithm involved the organization of the sensor nodes into the specific clusters,where each cluster possesses the same number of sensor, and the responsibility for this task lies with the FCM algorithm to form balanced clusters.

It should be noted that the whole clusterspossess their respectiveCluster Heads (CHs). The selected CHs are chosen according to the nodes' residual energy, and their remoteness from the cluster centroid. The rotation of the CH among cluster members through is not in each round like LEACH, but based on energy threshold (E_{th}) value. In this work, the fixed clusters are forming first then the CH is selected inside each cluster.

A. **Cluster Formation Algorithm**

Fuzzy c-means is a clustering techniquethatenablesa piece of sensor node to be a member to two or more clusters. This development of this technique was carried out by Dunn in 1973, and is further enhanced by Bezdek in 1981 [27]. It should be noted that fuzzy clustering entails each point possessing alevel of membership toother clusters, similar to fuzzy logic, instead of being the sole full membership to a cluster only. Hence, the points peripheral to a cluster, are lesser in terms of the level of membership in comparison to the points positioned in centralposition ofthe cluster. It is considered as one of the most efficient protocols [28], in numerous real-world situations, the utilization of the fuzzy clustering techniques are for addressingambiguity,fuzziness, and obscurity.Fuzzy clustering is considered as an effective clustering method. Out of all the fuzzy clustering techniques, the utilization of the fuzzy C-means (FCMs) algorithm are the most prevalent in the clustering procedures[29]. The minimization of the sum of distances between the case in time and the cluster centers is the objective of FCM.The objective of WSNs, the aim is in the clustering of the N sensor nodes into k determined clusters. The FCMfunctional aimis to cluster the WSNs according to the following formulation:

$$J = \sum_{i=1}^{n}\sum_{j=1}^{k} \mu^m \, d(x_i, x_c)^2 \text{ ,} i = 1, 2, \ldots, n \qquad j = 1, 2, \ldots, k$$

$$\mu_{ij} = \frac{1}{\sum_{j=1}^{k} \left(\frac{d(x_i, c_j)}{d(x_i, c_k)}\right)^{\frac{2}{m-1}}}$$

$$C_j = \frac{\sum_{i=1}^{n} (\mu_{ij})^m * d(x_i, c)}{\sum_{i=1}^{n} (\mu_{ij})^m}$$

Where μ is the membership of node *i* to cluster *j*, *m* is the value of fuzzifier is usually chosen as 2 in the most of applications [30]. And C_j refers to cluster centroid.

B. Selection and rotation of the Cluster Head

In the first round,we made the assumptionthat in anuncomplicatedexemplar for the radio hardware energy dissemination, the transmitter disseminates energy for the operation of the radio electronics and the power amplifier, and energy is disseminated by the receiverfor the operations of the radio electronics. With regards to the experiments explainedherewith, the free space and the multipath fading channel paradigms were enforced, which are dependentupon the proximity between the transmitter and receiver. Power control may be utilized to revert this wastethrough theproperinstallation of the the power amplifier—in instances when the distance is less than a distance threshold (d_0), the free space (fs) model is utilized; or alternatively, the multipath (*mp*) model is utilized. Hence, to transfer an *L* –bit data with a distance d, the radio expends E is:

$$E_{TX}(l, d) = \begin{cases} E_{elec} * l + \varepsilon_{fs} * l * d^2, & d \leq d_0 \\ E_{elec} * l + \varepsilon_{fs} * l * d^4, & d > d_0 \end{cases}$$

From the (4), in the case of transmitting the same data, the selected cluster head which has energy less than E_{TX} is not capableof conveying the sensing data to BS. To overcome this problem, a distributed mechanism is considered a node's residual energy to be thelimitation in choosing the Cluster Head. In addition, to reduce the intra-transmission distance, the distance to cluster centroid is relied as a second parameter to CH selection. The node has maximum value of objective function in the cluster, and can be selected as a CH:

Objective function (j) = max[$E_r(i) / d_c(i)$*]*

Where E_r is indicated the residual energy of node (i) and d_c is the distance from node (i) and cluster centroid. To eliminate the network instability by selectingthe CH in each round, the rotation of CH among member of cluster is done after several rounds based on energy Threshold value (Eth). The proposed algorithm is illustrated in the Figure 1.

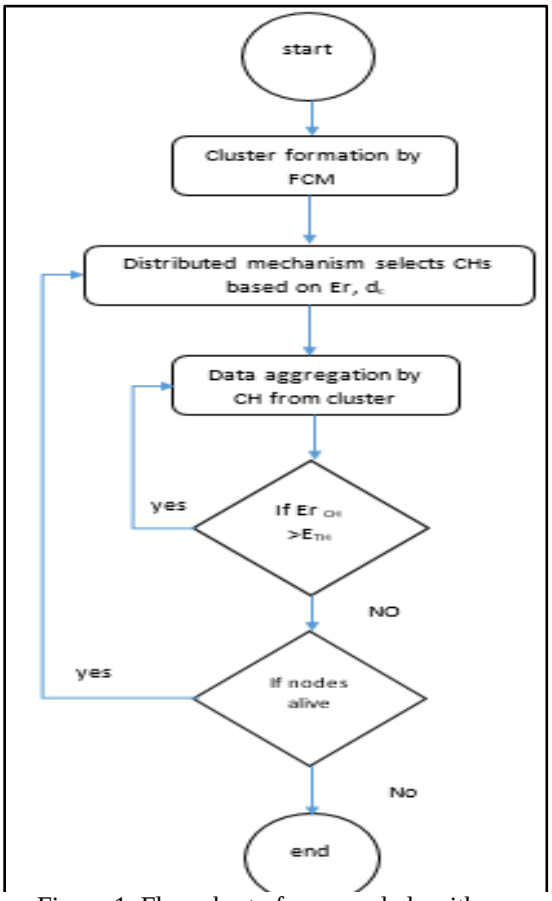

Figure 1. Flow chart of proposed algorithm

V. EXPERIMENTS AND RESULTS

As for our experiment, we carried out our evaluation using MATLAB. We recorded the total surplus energy and the number of surviving nodes to analyze the agreement of energy efficiency. In the scenario, the nodes are randomly generated. In the following table, the parameters for the experiments are summarized:

Table 1: Simulation parameters & values

Parameter	value
Network size	100 × 100
Number of sensor nodes	100
BS location	50 × 150
Initial Energy E_{ini}	1 J
E_{elect}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
Data packet size	3200 bit
Number of clusters	$\sqrt{N}$
Energy Threshold (E_{TH})	0.5 E_{ini}

The residual energy and network lifespan are the assessment metrics utilizedin theperformance evaluation of the protocols chosen for the comparison. Certain Wireless Sensor Network applications necessitatethe working order assurance of every sensor for guaranteeing the favorable network coverage. Hence, the measurement of the applications' network lifespan is gauged from the lifespan of the most short-lived node. Certain alternative applicationsneed aparticular nodes percentagetoremain alive forthe achievement of network goals. Thus, our simulation had indicated that the gauging of the network lifespan is achievedvia three differing metrics; First Node Dies(FND), Half Nodes Die (HND), andLast Node Dies (LND).

- Energy consumption (Ec): the definition for the energy consumption metric is the average energy utilization in the nodes in totality at a particularcourse of turns.
- First Node Dies (FND): it entails the duration taken in the course of turnsup to the point whenone of the nodes hasfinisheditsentire energy.
- Half Nodes Die (HND): it entails the duration taken in the course of turnsup to the point when half of the nodes have finished their entire energy.
- Last Node Dies (LND): it entails the duration taken in the course of turnsup to the point when allthe nodes in totality have finished their entire energy.

A comparison of therecommended algorithm to Hybrid algorithm [11] and LEACH [12] algorithms was made in association with the total energy consimption, and the network lifespan as indicated in Figure 2 and 3, respectively. It isnoted the utilization of energy in the recommended algorithm was reduced, and the lifespan of the network was extended. Thisis due to the LEACH algorithm, where the CHs are selected randomly in each round, andoccasionally, these nodes did not have sufficient energy for the receiving and the transmission of data to the BS. In addition, there is some nodes selected many time to act as a CH more than others. In addition, the hybrid algorithm involved a lot of message to select CHs in each round. Therefore, energy of nodes in both algorithms is exhausted quickly which leads decrease network lifetime.

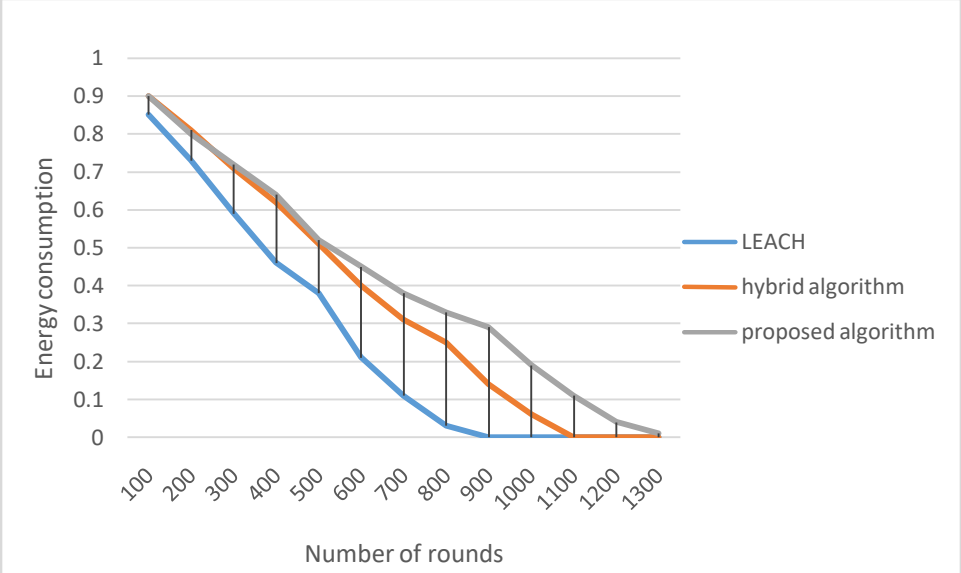

Fig. 2. The total energy consumption

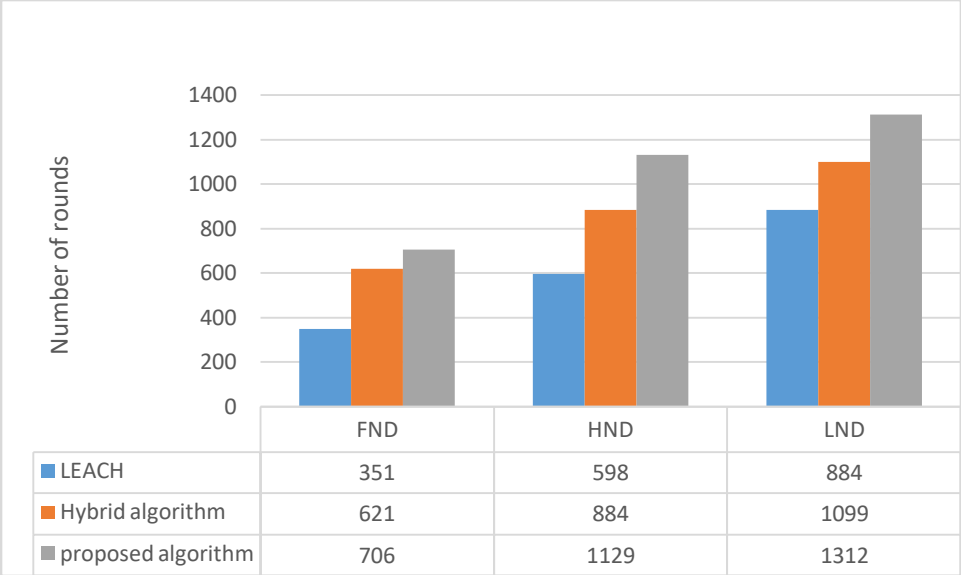

Fig. 3. Network lifespan

VI. CONCLUSION

Thecurrent study contained our considerationon a renowneffective energy clustering algorithm for Wireless Sensor Networks termed as LEACH algorithm, and recommended aninnovative clustering algorithm founded on the method. With thismethod, we overcome the imbalanced clusters formation problem in LEACH algorithm through the application of FCM algorithm to produce balanced clusters. In addition, the cluster head is chosenfromindividual cluster based on node energy, in addition to theremoteness from the cluster centroid rather than the randomly selected in LEACH. Additionally, the rotation of the cluster head is done based on specific threshold to enhance the network stability. The evaluation is conducted through theutilization of MATLAB, and the outcomesindicated our proposed LEACH algorithm to be superior than Hybrid algorithm.The said algorithms are superior in terms of energy consumption and network lifetime. In the future, we endeavor to develop this work by relying on additional parameters to enhance the selection of Cluster Heads.

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