Improving WSNs execution using energy-efficient clustering algorithms with consumed energy and lifetime maximization

Mohanad Sameer Jabbar[1], Samer Saeed Issa[2], Adnan Hussein Ali[3]
[1]Department Medical Instruments Techniques Engineering, Technical College of Engineering, Albayan University, Baghdad, Iraq
[2]Department Computer Science, Al-Rafidain University, Baghdad, Iraq
[3]Department of Electrical Techniques, Institute of Technology, Middle Technical University, Baghdad, Iraq

Article Info

Article history:

Received Jun 25, 2022
Revised Oct 13, 2022
Accepted Oct 24, 2022

Keywords:

Balancing consumed energy
Energy-efficient clustering
FLH-P proposal algorithm
Network lifetime
Wireless sensor networks

ABSTRACT

Wireless sensor networks (WSNs) has a major designing feature representing by energy. Specifically, the sensor nodes have limited battery energy and are deployed remote from base station (BS); therefore, the actual enhancement dealing with energy turns into the Clustering routing protocols fundamentals which concerned in network lifetime improvement. Though, unexpected and energy insensible of the clusters head (CH) selection is not the best of WSN for greatly lowering lifetime network. A presentation article of an WSNs incoming routing approach using a mix of the fuzzy approach besides hybrid energy-efficient distributing (HEED) algorithm for increasing the lifetime and node's energy. The FLH-P proposal algorithm is split into two parts. The stable election protocol HEED approach is used to arrange WSNs into clusters. Then, using a combination of fuzzy inference and the low energy adaptive clustering hierarchy (LEACH) algorithm, metrics like residual energy, minimal hops, with node traffic counts are taken into account. A comparison of FLH-P proposal algorithm with LEACH algorithm, fuzzy approach, and HEED utilizing identical guiding standards was used for demonstrating the performance of the suggested technique from where corresponding consumed energy as well as lifetime maximization. The suggested routing strategy considerably increases the network lifetime and transmitted packet throughput, according to simulation findings.

Corresponding Author:

Mohanad Sameer Jabbar
Department Medical Instruments Techniques Engineering, Technical College of Engineering
Albayan University
Baghdad, Iraq
Email: mohanad.s@albayan.edu.iq

1. INTRODUCTION

Wireless sensor networks (WSN) have received a great deal of interest in recent years. More and more intelligent sensors have emerged as a result of the advancement of microelectromechanical system (MEMS) technology. These sensors are smaller than standard sensors, have less processing and computational resources, and are less expensive. The utilizing of smart sensor nodes for sensing, measuring, then collecting data as of their surroundings. Sensors providing users with the acquired data via a variety of confined decision-making mechanisms [1]. Microelectronics advancements have accelerated the creation of compact, unexpansive, and apparatus with low-power that can sense surroundings besides process large amounts of data. These advancements may be fuelled partly by quick advancements of internet of things (IoT) conception as well as the need to connect, enabling requests like smart cars, controlling of traffic schemes, smart homes, digital twins, also for more conceivable [2]. Such programs must gather data coming obtained with monitoring process then transmit it for computing location [3].

WSNs don’t require the assistance of a network connection, wide range of presentations related to military objective concerning bath track and supervising, regular disasters retrieve, monitors of health care, harmful environments investigation, detecting of remote earthquakes, as well as others [4]. A WSN is a collection of wirelessly networked multifunctional devices, known as sensor nodes or simply nodes, that are positioned in an area of interest with at least one sink node, known as a base station (BS). The BS has the ability to exercise centralized control over the network it is a part of, as well as connect with network end users and/or other wireless or wired networks (Figure 1) [5].

FBattery power, computing, sensor mobility, and communication capabilities are all limits that WSN faces. The selection of CH, creation of clusters, in addition to administration of a cluster member’s equation number are the primary issues in clustering (CMs). Several clustering techniques have been suggested, including LEACH, which is a well-known WSN algorithm. Clustering considers factors such that effective energies, positions, mobilities, and besides complication [6]. A typical sensor node is an electronic device that includes a processing unit, a communication module, one or more sensing devices, and a power unit, as illustrated in Figure 2. Optional equipment such as a mobility module or a location tracking module may be included. A sensor node collects data about its surroundings using its sensing components. A sensor node's processing unit handles the data it collects, and its communication module exchanges data wirelessly with other sensor nodes and the BS. A battery is commonly used as the power source [7]. The sensor node's current location is tracked by the position tracking module. Finally, the mobility unit allows for transfer.

WSNs are indeed positioned in remote locations where humans can't acquire nearby with energy can't be recharged. As WSN consider compact and power-driven by battery, they have a number of drawbacks, including restricted processing plus storing capacity, communicated range is restricted, as well as imperfect energy [8]. A most pressing concern is energy. In multi-hop WSNs, uneven energy usage is a concern. A considerable portion of the network lifespan is lost due to inconsistencies in energy use. Because of the death of certain nodes, the entire network might be separated, eventually resulting in the network's end. The lifetime of a WSN be important criterion to evaluate routing protocol performances [9]. As a result, developing a successful strategy to limit energy loss is critical to extending the network's lifetime.

In low energy adaptive clustering hierarchy (LEACH) protocol, there are two processing steps, a setup phase and a steady phase. Sensors are organized into groups, or clusters, during the setup phase, and data aggregation and transmission of detected data are done in steady state. Many alternative enhanced variants of LEACH have been proposed [10] due to LEACH's limitations. In order to optimize LEACH, the clusters head (CH) is chosen based on factors such as energy and network address. The value of the CH threshold is dynamically changed based on the network address. The LEACH procedure has been improved by the addition of two levels CH, one of which is closer to the BS while other is dependent on constraints of energy. As a result, the use of two CH assures a low energy drop on the network.

Liao *et al*. [11] who assessed the distances and distributed density was employed an equal opportunity clustering method by way of distributed WSNs self-organization, taking into consideration an ideal cluster structure. As a result, it differs significantly from prior clustering techniques. For clustered heterogeneous WSNs, a stable election protocol (SEP) utilized for extend the period before the initial node dies, that considers critical for multiple implementation everyplace sensor network feedback ought to be dependable. SEP depends on the weighted appointment probability of becoming a CH from any node depending on which node has residual energy [12]. A mix of fuzzy and clustering methods was used by some of the researchers.

Zytoune *et al*. [13] introduced a routing protocol that has regular balancing-energy that chose larger residual energies nodes than a particular threshold by means of routers with respect to further nodes and divided the energy burden across any sensors for maximization an overall network lifetime at every transmission round. The clustering with fuzzy-logic-based methodology which have an energy predicting addition was developed by Lee and Cheng [14] to extend the lifetime of WSNs by equally distributing the load using the fuzzy approach. It chooses the CHs based on the sensor nodes' estimated residual energy. Regarding the equilibrium of consumed energy and network lifetime maximization, Al-Alshawi *et al*. [15] introduced a combination of a fuzzy technique and an A-star algorithm. The authors compared the suggested technique to the fuzzy approach utilizing similar routing conditions at distinct topographical regions, utilizing many fuzzy parameters such as the nominal traffic loads, greatest that battery power remains, and minimum hops number.

Azooz *et al*. [16], LEACH is improved as R-LEACH, that gives a selected CH process centred on a node's original energy, remaining energy, in addition to network's ideal CHs number. They presented the LEACH-C centralized technique. LEACH-C is an update to the LEACH protocol. Any network’s node sends data of position with remaining energy toward sink node in LEACH-C. A sink node clusters received data and calculates the best CH for each cluster based on the results. Communication overhead is enhancing throughout the procedure of re-clustering due to LEACH-centralized C's nature. For wireless sensor networks, a sleep-wake energy-efficient distributed clustering technique (SEED) was suggested in [17]. To accomplish equitable energy distribution, SEED separates the sensing network for many zones instituted on how energy standard as low, high, or advancing. Nodes with a lot of leftover energy at an individually zone for only turning into CHs in SEED. Also, protocol of energy centrally clustering routing (ECCR) was suggested for WSNs. Clusters may be preset or static in ECCR, and a chosen of CHs are depending on the node order, which is made up of the node's remaining energy and typical distance with member nodes [18]. A high order node have a high remaining energies in addition to a little average distances. The fundamental purposing of this work is to develop a strategy that will help WSNs lifetime by minimizing energy costs and distributing energy use evenly. We employ both the Fuzzy method and the LEACH-HEED algorithms to do this.

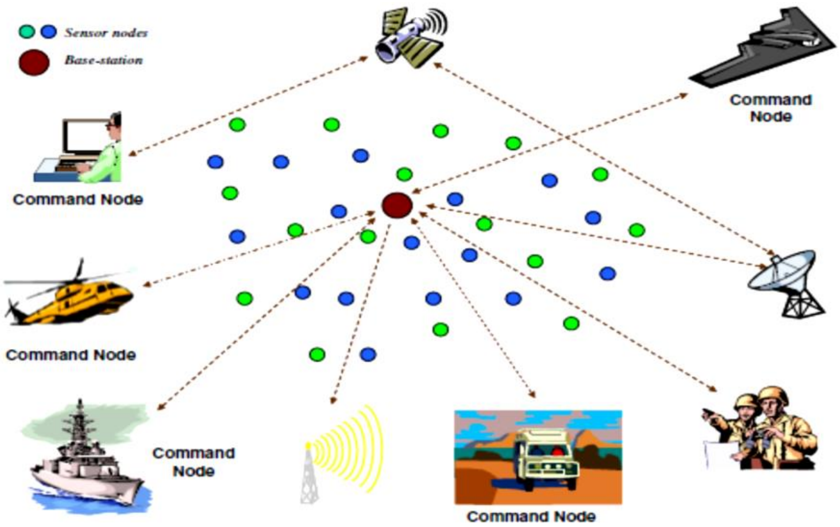

Figure 1. WSN collection [4]

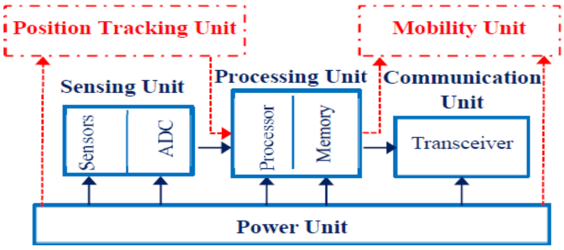

Figure 2. The architecture of a typical sensor node

2. PRELIMINARIES

Explaining In previous publications, the advantages and constraints of increasing network lifespan in WSN were considered. To address LEACH's traditional difficulties, the energy-efficient technique created on LEACH and presented by [19]. An idea with routing metrics, that may be utilized as WSNs lifetime extension, as well as several expectations upon which completely work may be based. The sensor’s sink and size of coordinators field can be recognized since sensors are spread randomly (uniformly) and are not movable, and not constrained energy of the sink, at least in relation to another sensor’s nodes energy [20]. The position of the base station considers static and remote as of the network's sensor’s nodes. Then in heterogeneous sensor networks, a fraction population of nodes seems to have energy higher than the node remainder at network; such that case when the nodes are equally space distribution. The network's aggregate energy may be sent to each node and adjust likelihood of chosen CHs based on their leftover energy [21]. All sensor nodes are dispersed at random around the region, moreover, every sensor node has been designed to detect its own location, the positions related for neighbours and sink nodes. The base station creates and sends the routing schedule to every node. A method of A-star can be utilized to determine a best route between the node and BS.

2.1. Hybrid clustering algorithms

The main goal of clustering algorithm with probabilistic selected type will be a network's lifetime increasing as well as scalability, but also a minimization and distribution the consumed energy [22]. The entire network is split up into virtualized squares grids, each of which corresponds to a different zone. The grid creation and cluster head selection processes are started by BS at the beginning of the network topology construction process. The most well-known protocols under this group include LEACH, energy-efficient hierarchical clustering (EEHC), hybrid energy-efficient distributing (HEED) and its expansions.

2.2. LEACH algorithm

The LEACH protocol would be a single-hop, distributing, deterministic, hierarchically protocol. According to the receiving signal strength analyzer, LEACH creates the clusters. Furthermore, the LEACH's CH nodes serve as routers to the BS. The cluster is where all information gathering, including data fusion & aggregating, takes place. LEACH which fulfilled the unique requirements of WSNs, included increasing the lifetime of WSNs and reducing SN energy consumption, was initially suggested by Heinzelman *et al*. [23]. LEACH would be a distribution protocol with no need for a central management system that allows nodes to make choices independently. Since every node does have an equal chance of becoming a CH, the energy utilized by each SN every round is balanced. LEACH, which gives SNs an equitable opportunity to be selected as a CH, often offers a good representation of energy use [24]. An SN cannot revert to becoming a CH in the round after being selected as a CH.

As an enhanced algorithm built on the LEACH protocol, the separation (SEP) algorithm is utilized for clustering techniques. By using the distinctive characteristics of heterogeneity with existing of proportion of advanced nodes and being the extra energy aspect added to normal nodes to become more advanced energy nodes. SEP enhances the stable region of the clustering hierarchy process [25]. Advanced nodes possess greater possibility than standard nodes of becoming cluster head, that is similar to a fairness limit on consumed energy, in order to prolong the stable phase time. The major goals of the SEP technique are to prevent low-energy nodes from being CHs, controlling the CHs numbers at an appropriate level, and reduce the unequal CHs distribution between rounds. By doing so, it is possible to lower energy costs and increase the network's lifetime.

Younis and Fahmy [26] presented HEED clustering. By employing two fundamental criteria to choose the CHs, they enhanced the LEACH procedure. The second parameter, which depends on cluster density or node degree, is the cost of intra-cluster communication. The first parameter is the amount of energy left in each node. Unlike the LEACH technique, the CH nodes in HEED are chosen in a methodical manner. The only SNs that have a possibility of becoming CH nodes are those that have more of the remaining energy. Two nodes within the communication range having a small likelihood of becoming CHs is another possibility [27]. The CH nodes are evenly distributed over the sensor field in HEED as compared to the LEACH protocol.

2.3. Fuzzy approach

Zadeh [28], fuzzy logic was first described in the middle of the 1960s. Since then, its uses in system identifying and adaptive controlling systems have increased exponentially. It benefits from being simple to implement, reliable, and capable of approximating any nonlinear mapping. A collection of linguistic fuzzy rules based on the knowledge of a human expert define the dynamic system's behaviour throughout fuzzy systems. A fuzzy system's core rules might be given by experts or can be deduced from numerical information. The rules that we are interested in may be written as a series of IF-THEN statements in either scenario. The usual structure of a fuzzy system is seen in Figure 3. It consists of four components namely; fuzzification, rule base, inference engine and defuzzification.

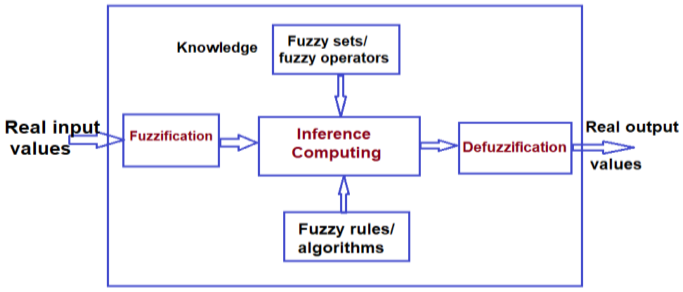

Figure 3. Typical structure of fuzzy approach

3. PROPOSED FLHP ALGORITHM

A significant aspect in evaluating the effectiveness of routing methods is the lifetime of a WSN. A considerable portion of the network lifetime is lost due to imbalanced energy use. Thus, the key challenge for extending the network lifetime is to design an efficient routing mechanism to limit energy losses. This paper's main objective is to develop a protocol that, by restricting the consumed energy and balancing the energy costs distributions, may increase network lifetime [29]. So, a suggestion of the FLH-P routing methodology, which applies the HEED algorithm, fuzzy approach, and LEACH method. By taking into account the three routing criteria, the proposal chooses the best node to build the multi-hop tree.

So, the feature of this proposed approach is network lifetime Improvement in WSN by composing the network with a combination of LEACH and HEED at one side and the applying of fuzzy logic approach in the other side for energy mitigating reasonable energy consumption in sensors [30]. The conventional LEACH protocol is enhanced by the proposed FLH-P with the selection of best CH and helper CH using parallel operating optimization algorithms. Also, an addition of probability link in addition to decisive indexing are applied for decision-making process for handling the cluster size that considers the drawbacks in LEACH. Based on the estimated metric the decision is made and either the cluster is split into two or merged into one. While the selection of the best channel to transmit the collected data to sink without any packet loss. A MATLAB software considers the simulation tool for better realization of delay, consumption of energy, throughput, counts of alive nodes and packet loss.

4. SIMULATION ENVIRONMENT

In this section, software MATLAB is used for the implementation in this suggested WSN system. The discrete-event network tool that covers all the functions of sensor nodes is how this FLH-P is modelled. In the environment is sensed by the sensor, measurements are sent as packets. Each packet is made up of a single buffer and has a header with the data appended to it. The suggested methodology is compared to the LEACH algorithm and the fuzzy approach to show how well it balances energy usage and maximizes network longevity. The remaining energy, the smallest hop, and the traffic load are the same routing parameters that are used by all three of these algorithms to determine the best route from the source node to the sink node.

Table 1 includes a few major system model characteristics but does not limit there. The above-discussed methods for clustering, head selecting, scheduling, as well as selecting channels are all utilized to create the suggested lifetime enhanced WSN environment. By putting the suggested algorithms into practice in this simulated environment, the outcomes are assessed. MATLAB is used to run the simulations. A 400 m by 400 m area with 300 sensor nodes randomly placed has a perceived transmission limit of 30m. There is a data sink node at (0, 50). The starting energy of 4J is shared by all sensor nodes. The first order radio model, which is widely utilized in the domain of evaluating routing protocols in WSNs, is employed in the suggested technique.

Table 1. Characteristics MATLAB model of the simulation

Symbol	Specification	No.
N	Number of nodes	300
W	length of the network	400
L	width of the network	400
Ei	Initial energy of each node (joules)	4
CHpl	Packet size for cluster head per round (bits)	3000
p	desired percentage of cluster heads	5/100
R	Range for cluster	50
pMin	Lowest possible CH_prop	10^-4
max_rounds	Max Number of simulated rounds	2000
NonCHpl	Packet size for normal node per round (bits)	300
Tsetup	average Time in seconds taken in setup phase	4
Tss	average Time in seconds taken in steady state phase	10
Etrans	Energy for transmitting one bit	1.0000e-05
Erec	Energy for receiving one bit	1.0000e-05;
Eagg	Data aggregation ener	1.0000e-07;
Efs	Energy of free space model amplifier	0.3400e-9

An advanced nodes have an initial energy in this clustering routing techniques is 4 J, while the regular nodes initial energy is 1 J. A 300 bits' nodes message size which will be send to specified CHs and also the aggregated messages which CH transmitted to the sink node have the same size. The initial CH ratio is 0.2 with a packet size of 3000 bits.

4.1. Implementation of FLH-P algorithm

There are two stages in the FLH-P algorithm. First, cluster the wireless sensor network using the stable election protocol (LEACH) method. There are two types of nodes: advanced and normal. The energy of the advanced node is double that of the standard node. To ensure an equitable distribution of the CH, it is suggested that the candidate nodes run for the CH based on the residual energy that falls within a specific range. Second, among the CH nodes, the fuzzy inference is paired with HEED algorithms to find the optimum path from the source node to the destination node while taking into consideration the residual energy, minimum hops count, and traffic loads of each CH. Figures 4 and 5 present the results using the FLH-P routing method to find the optimal route.

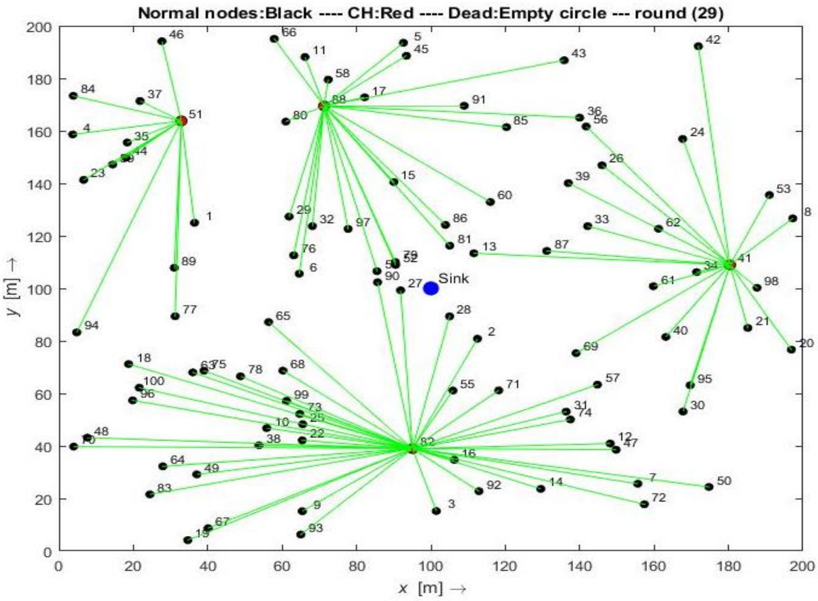

Figure 4. FLH-P routing method

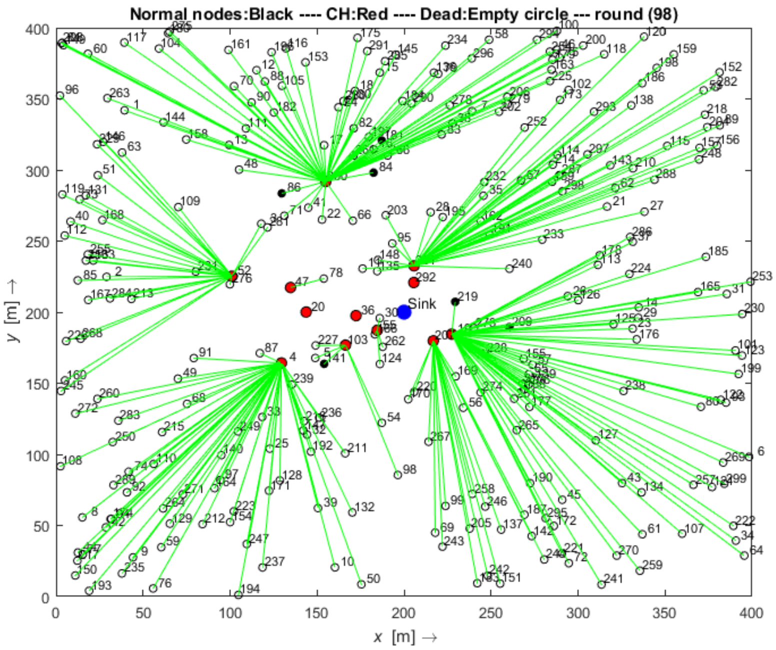

Figure 5. Optimum method of FLH-P routing

4.2. Energy model

When the energy reached zero, the node perished since it could no longer be relocated after being put. The first-order wireless model that is often utilized in WSNs was employed in the experiment. In this article, there are two categories for the consumed energy used by the sensor nodes. The energy used by the basic or advanced node comes first (non-CH and nonparent node). The energy used by the CH or parent node comes next (PN). In the same way as a CH or PN, data processing also uses energy, in addition to delivering and receiving messages.

4.3. Alive nodes

Figure 6 show the simulation results for nodes being alive distributed configuration. It can be seen that the number of nodes alive in the proposed method is always higher than that of LEACH, and HEED algorithms. The Figure 6 can also show that the performance of these algorithms is obviously affected by the topographic regions. The HEED and LEACH algorithm performance varies greatly in the 600-1000 rounds: Distribution of the nodes being alive according to the number of rounds. In Figure 6, the survival rate of nodes for HEED and LEACH algorithms lower than the FLH-P proposed algorithm, while the FLH-P algorithm has achieved good performance. The FLH-P algorithm has a strong adaptive capacity under different network topologies.

As can be observed in Figure 6, the proposed technique consistently has a greater number of active nodes than the LEACH and HEED algorithms. It can also demonstrate how topographic areas have a clear impact on how well these algorithms function. The distribution of the nodes that are alive varies significantly between rounds 600 and 1000 for the HEED and LEACH algorithms. Figure 6 shows that the FLH-P technique has performed well, whereas the survival rates of nodes for the HEED and LEACH algorithms are lower. Under various network topologies, the FLH-P algorithm has a great potential for adaptation.

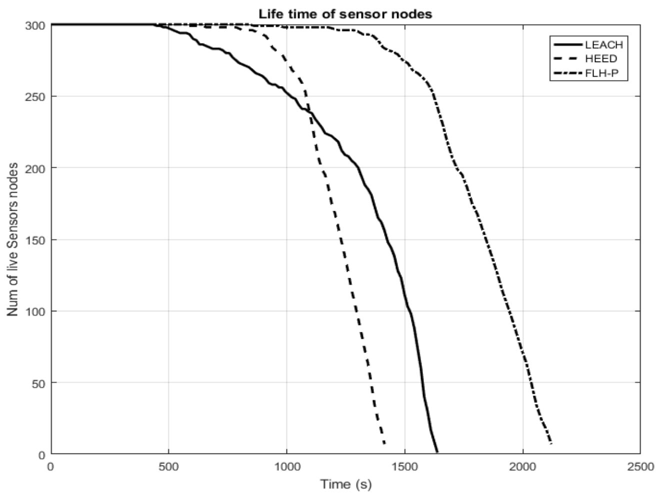

Figure 6. Alive nodes numbers vs rounds for different approaches

4.4. Throughput effectiveness

Throughput is a significant factor in determining how well data transfer performances are achieved. It represents how many packets were successfully sent at the specified time. The improvement in throughput reveals the level of connectivity that tends to effectively complete the transfer. Network congestion and packet loss are the two main factors that reduce throughput. Multiple nodes participating in simultaneous communication causes network congestion. The FLH-P approach is used in our proposed WSN system model to provide precise timing for nodes. As a result, only nodes in the transmission state will transfer data to CH/HCH, entirely avoiding network congestion.

The throughput figures are shown in Figure 7 for comparison. The proposed approach is contrasted with LEACH and HEED. This comparison shows that the proposed FLH-P has a high throughput compared to comparable systems. The optimal transmission route was chosen, considerably reducing packet loss, which resulted in an increase in throughput. Therefore, reducing packet loss will save unnecessary retransmissions, which also use energy. The planned FLH-P has a throughput that is around 60% more than LEACH's and 20% greater than HEED's.

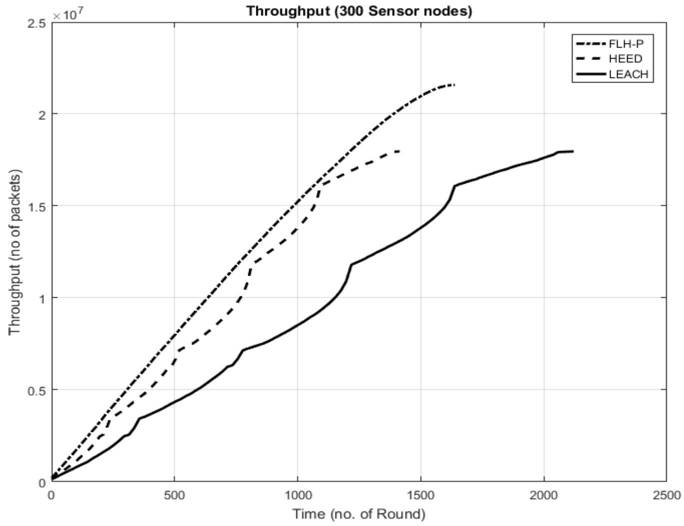

Figure 7. Throughput vs rounds for different approaches

4.5. Energy consumed effectiveness

Because sensor nodes require battery assistance, the amount of energy spent by sensors is crucial to the WSN network. Energy is used by sensor nodes during data transmission and sensing. By carefully planning the actions of sensor nodes, this energy usage may be reduced. The comparison figure for the node's energy usage is shown in Figure 8. The ordinary LEACH uses more energy than the HEED and suggested FLH-P in this comparison. Energy usage in LEACH is comparably high as a result of the constraints and troublesome concerns listed above. In the suggested work, FLH-P is introduced to choose the best CH/HCH, which avoids frequent head selection and improves energy consumption by conserving energy during sleep stages. If the scheduling is done in a balanced manner, there is possibility for this task.

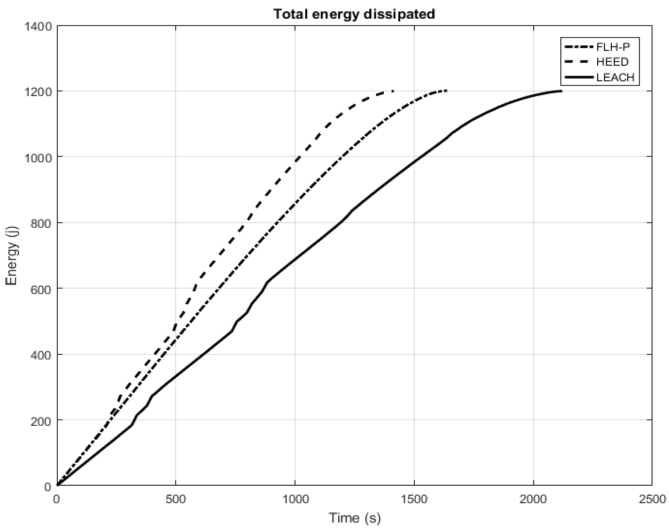

Figure 8. comparison for the node's energy usage

The first most important statistic in WSN is network lifetime, and is the objective of this article. The number of maintained living sensor nodes in the proposed network is used to determine network lifetime. The optimal performance of the system model with the suggested algorithms is implied by an increase in network lifetime. Clustering, which is the best approach, is mostly used to increase WSN network lifetime. A weak cluster formation process, on the other hand, results in increased energy consumption and a shorter network lifetime. The network lifetime is calculated based on the quantity of energy used.

5. CONCLUSION

Efficiency in energy use is crucial in wireless sensor networks as nodes rely on finite amounts of battery power. In the actual world, energy is a key consideration while developing WSNs. Sadly, the battery's energy is finite by nature. Therefore, the most crucial factor in energy use is efficiency. Numerous algorithms have been developed to increase energy efficiency. A network lifespan enhanced WSN system model is built and integrated with LEACH, HEED, and fuzzy technique in this suggested article. These techniques are used to choose a CH and HCH for balancing energy usage and concurrent data collection. Members carry out sensing and communicate the sensed data in accordance with the timeslots, whilst the cluster head receives data and transfers it to the sink. Dynamic fuzzy is used to get the most effective channel for transmission during head transmission. By determining the perfect channel and allocating time slots, improvements in throughput, packet loss, and latency can be addressed. The suggested approach offers an effective CH declaration procedure to decrease the probability of re-clustering, thereby reduces control packet overhead and increases CH lifetime. In comparison to the current clustering technique, simulation results show that the proposed system lowers re-clustering frequency and management overhead, increases network lifetime, and optimizes energy usage. It has been shown that a considerable reduction in the energy consumption of nodes closer to the sink can lengthen the lifetime of WSNs.

REFERENCES

[1] R. Azizi, “Consumption of energy and routing protocols in wireless sensor network,” *Network Protocols and Algorithms*, vol. 8, no. 3, p. 76, Dec. 2016, doi: 10.5296/npa.v8i3.10257.

[2] M. M. Kareem, M. Ismail, M. A. Altahrawi, N. Arsad, M. F. Mansor, and A. H. Ali, “Grid based clustering technique in wireless sensor network using hierarchical routing protocol,” in *ISTT 2018 - 2018 IEEE 4th International Symposium on Telecommunication Technologies*, Nov. 2018, pp. 1–5, doi: 10.1109/ISTT.2018.8701720.

[3] X. Yan, C. Huang, J. Gan, and X. Wu, “Game theory-based energy-efficient clustering algorithm for wireless sensor networks,” *Sensors*, vol. 22, no. 2, p. 478, Jan. 2022, doi: 10.3390/s22020478.

[4] M. M. Monowar, “An energy-aware multi-constrained localized QoS routing for industrial wireless sensor networks,” *Ad-Hoc and Sensor Wireless Networks*, vol. 36, no. 1–4, pp. 21–50, 2017.

[5] S. A. S. Lafta, M. M. Abdulkareem, R. K. Ibrahim, M. M. Kareem, and A. H. Ali, “Quality of service performances of video and voice transmission in universal mobile telecommunications system network based on OPNET,” *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 10, no. 6, pp. 3202–3210, Dec. 2021, doi: 10.11591/eei.v10i6.3139.

[6] A. Mehmood, S. Khan, B. Shams, and J. Lloret, “Energy-efficient multi-level and distance-aware clustering mechanism for WSNs,” *International Journal of Communication Systems*, vol. 28, no. 5, pp. 972–989, Mar. 2015, doi: 10.1002/dac.2720.

[7] T. Mu and M. Tang, “LEACH-B: An improved LEACH protocol for wireless sensor network,” in *2010 6th International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2010*, Sep. 2010, pp. 1–4, doi: 10.1109/WICOM.2010.5601113.

[8] R. Ashween, B. Ramakrishnan, and M. Milton Joe, “Energy efficient data gathering technique based on optimal mobile sink node selection for improved network life time in wireless sensor network (WSN),” *Wireless Personal Communications*, vol. 113, no. 4, pp. 2107–2126, Aug. 2020, doi: 10.1007/s11277-020-07309-y.

[9] J. Yuea, W. Zhang, W. Xiao, D. Tang, and J. Tang, “Energy efficient and balanced cluster-based data aggregation algorithm for wireless sensor networks,” *Procedia Engineering*, vol. 29, pp. 2009–2015, 2012, doi: 10.1016/j.proeng.2012.01.253.

[10] Z. Zhao, K. Xu, G. Hui, and L. Hu, “An energy-efficient clustering routing protocol for wireless sensor networks based on AGNES with balanced energy consumption optimization,” *Sensors (Switzerland)*, vol. 18, no. 11, 2018, doi: 10.3390/s18113938.

[11] Y. Liao, H. Qi, and W. Li, “Load-balanced clustering algorithm with distributed self-organization for wireless sensor networks,” *IEEE Sensors Journal*, vol. 13, no. 5, pp. 1498–1506, 2013, doi: 10.1109/JSEN.2012.2227704.

[12] A. H. Ali, A. D. Farhood, and M. K. Naji, “Analysis of a framework implementation of the transceiver performances for integrating optical technologies and wireless LAN based on OFDM-RoF,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 4, pp. 4252-4260, Aug. 2020, doi: 10.11591/ijece.v10i4.pp4252-4260.

[13] O. Zytoune, M. El Aroussi, and D. Aboutajdine, “A uniform balancing energy routing protocol for wireless sensor networks,” *Wireless Personal Communications*, vol. 55, no. 2, pp. 147–161, 2010, doi: 10.1007/s11277-009-9791-3.

[14] J. S. Lee and W. L. Cheng, “Fuzzy-logic-based clustering approach for wireless sensor networks using energy predication,” *IEEE Sensors Journal*, vol. 12, no. 9, pp. 2891–2897, Sep. 2012, doi: 10.1109/JSEN.2012.2204737.

[15] I. S. AlShawi, L. Yan, W. Pan, and B. Luo, “Lifetime enhancement in wireless sensor networks using fuzzy approach and A-star algorithm,” in *IET Conference on Wireless Sensor Systems (WSS 2012)*, 2012, vol. 2012, no. 601 CP, pp. 8B2-8B2, doi: 10.1049/cp.2012.0611.

[16] S. Mahdi Azooz, J. H. Majeed, R. Khalid Ibrahim, and A. Hussein Ali, “Implementation of energy-efficent routing protocol within real time clustering wireless sensor networks,” *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 11, no. 4, pp. 2062–2070, Aug. 2022, doi: 10.11591/eei.v11i4.3916.

[17] G. Ahmed, J. Zou, M. M. S. Fareed, and M. Zeeshan, “Sleep-awake energy efficient distributed clustering algorithm for wireless sensor networks,” *Computers & Electrical Engineering*, vol. 56, pp. 385–398, Nov. 2016, doi: 10.1016/j.compeleceng.2015.11.011.

[18] M. M. Kareem, S. A. S. Lafta, H. F. Hashim, R. K. Al-Azzawi, and A. H. Ali, “Analyzing the BER and optical fiber length performances in OFDM RoF links,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 23, no. 3, pp. 1501-1509, Sep. 2021, doi: 10.11591/ijeecs.v23.i3.pp1501-1509.

[19] W. Huang, Y. Ling, and W. Zhou, “An Improved LEACH routing algorithm for wireless sensor network,” *International Journal of Wireless Information Networks*, vol. 25, no. 3, pp. 323–331, Sep. 2018, doi: 10.1007/s10776-018-0405-4.

[20] M. A. Saad, H. J. Alhamdane, A. H. Ali, S. Alani, M. M. Hashim, and B. Hasan, “Total energy consumption analysis in wireless mobile ad hoc network with varying mobile nodes,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 20, no. 3, pp. 1397-1405, Dec. 2020, doi: 10.11591/ijeecs.v20.i3.pp1397-1405.

[21] X. Huan, K. S. Kim, S. Lee, E. G. Lim, and A. Marshall, "A beaconless asymmetric energy-efficient time synchronization scheme for resource-constrained multi-hop wireless sensor networks," *IEEE Transactions on Communications*, vol. 68, no. 3, pp. 1716–1730, Mar. 2020, doi: 10.1109/TCOMM.2019.2960344.
[22] S. Chamanian, S. Baghaee, H. Ulusan, O. Zorlu, E. Uysal-Biyikoglu, and H. Kulah, "Implementation of energy-neutral operation on vibration energy harvesting WSN," *IEEE Sensors Journal*, vol. 19, no. 8, pp. 3092–3099, Apr. 2019, doi: 10.1109/JSEN.2019.2890902.
[23] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences*, 2000, vol. vol. 1, doi: 10.1109/HICSS.2000.926982.
[24] M. K. Abed, M. M. Kareem, R. K. Ibrahim, M. M. Hashim, S. Kurnaz, and A. H. Ali, "Secure medical image steganography method based on pixels variance value and eight neighbors," *2021 International Conference on Advanced Computer Applications, ACA 2021*, pp. 199–205, 2021, doi: 10.1109/ACA52198.2021.9626807.
[25] B. H. Hameed, A. Y. Taher, R. K. Ibrahim, A. H. Ali, and Y. A. Hussein, "Based on mesh sensor network: design and implementation of security monitoring system with Bluetooth technology," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 26, no. 3, pp. 1781-1790., Jun. 2022, doi: 10.11591/ijeecs.v26.i3.pp1781-1790.
[26] O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *IEEE Transactions on Mobile Computing*, vol. 3, no. 4, pp. 366–379, Oct. 2004, doi: 10.1109/TMC.2004.41.
[27] A. Mehmood, J. Lloret, and S. Sendra, "A secure and low-energy zone-based wireless sensor networks routing protocol for pollution monitoring," *Wireless Communications and Mobile Computing*, vol. 16, no. 17, pp. 2869–2883, 2016, doi: 10.1002/wcm.2734.
[28] L. A. Zadeh, "The role of fuzzy logic and soft computing in the conception and design of intelligent systems," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 695 LNAI, 1993, pp. 1–1,doi: 10.1007/3-540-56920-0_1.
[29] N. A. Al-Aboody and H. S. Al-Raweshidy, "Grey Wolf optimization-based energy-efficient routing protocol for heterogeneous wireless sensor networks," *2016 4th International Symposium on Computational and Business Intelligence, ISCBI 2016*, pp. 101–107, 2016, doi: 10.1109/ISCBI.2016.7743266.
[30] H. F. Hashim, M. M. Kareem, W. K. Al-Azzawi, and A. H. Ali, "Improving the performance of photovoltaic module during partial shading using ANN," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 12, no. 4, pp. 2435-2442, Dec. 2021, doi: 10.11591/ijpeds.v12.i4.pp2435-2442.

BIOGRAPHIES OF AUTHORS

Mohanad Sameer Jabbar is Assistant professor at Al-Bayan University, Baghdad, Iraq in Technical College of Engineering, medical instruments techniques Engineering Department where he has been a faculty member since 2021. He graduated with a B.Sc. degree in mathematics since from Mustansiriyah university, Baghdad, Iraq and an M.Sc. in computer since from university of Singhania-Jhunjhunu, India in 2010 and Ph.D in computer since specialized in network and communication from university of Singhania-Jhunjhunu, India in 2013. His research interest in the area of network, communication, and network security. He can be contacted at email: mohanad.s@albayan.edu.iq.

Samer Saeed Issa is Assistant Professor at Al-Rafidain University College, Baghdad, Iraq, where he has been a faculty member since 2010. He graduated with a BsC. Degree in computer science from University of Technology-Baghdad, Iraq, in 1999, and an M.Sc. in Data Security from University of Technology-Baghdad, Iraq, in 2002, and Ph. D from Iraqi Commission for Computers and Informatics/Informatics institute for post graduate Studies-Baghdad in 2006. His research interests in the area of network and data security. He can be contacted at email: samer.saeed.elc@ruc.edu.iq.

Adnan Hussein Ali is Professor at the Middle Technical University, Baghdad, Iraq, where he has been a faculty member since 2007. He graduated with a Bs C degree in Electronic Engineering from University of Technology-Baghdad, Iraq, in 1987, and an M.Sc. in Electronic and communication technology from University of Technology-Baghdad in 1999, and Ph D from Laser and Opto-electronics Dept. University of Technology-Baghdad in 2007. His research interests in the area of optical communication, cloud computing, RoF, WSN, and PV. She is author/co-author of over 60 research publications. He can be contacted at email: dr.adnan@mtu.edu.iq and aaddnnaann63@gmail.com.