Computers, Materials & Continua
DOI: 10.32604/cmc.2022.024584
Article

Tech Science Press

Coyote Optimization Using Fuzzy System for Energy Efficiency in WSN

Ahmed S. Almasoud[1], Taiseer Abdalla Elfadil Eisa[2], Marwa Obayya[3], Abdelzahir Abdelmaboud[4], Mesfer Al Duhayyim[5], Ishfaq Yaseen[6], Manar Ahmed Hamza[6,*] and Abdelwahed Motwakel[6]

[1]Department of Information Systems, College of Computer and Information Sciences, Prince Sultan University, Saudi Arabia
[2]Department of Information Systems-Girls Section, King Khalid University, Mahayil, 62529, Saudi Arabia
[3]Department of Biomedical Engineering, College of Engineering, Princess Nourah Bint Abdulrahman University, Riyadh, 11671, Saudi Arabia
[4]Department of Information Systems, College of Science and Artsat Mahayil, King Khalid University, Saudi Arabia
[5]Department of Natural and Applied Sciences, College of Community-Aflaj, Prince Sattam bin Abdulaziz University, Saudi Arabia
[6]Department of Computer and Self Development, Preparatory Year Deanship, Prince Sattam bin Abdulaziz University, AlKharj, Saudi Arabia
*Corresponding Author: Manar Ahmed Hamza. Email: ma.hamza@psau.edu.sa
Received: 23 October 2021; Accepted: 09 February 2022

Abstract: In recent days, internet of things is widely implemented in Wireless Sensor Network (WSN). It comprises of sensor hubs associated together through the WSNs. The WSN is generally affected by the power in battery due to the linked sensor nodes. In order to extend the lifespan of WSN, clustering techniques are used for the improvement of energy consumption. Clustering methods divide the nodes in WSN and form a cluster. Moreover, it consists of unique Cluster Head (CH) in each cluster. In the existing system, Soft-K means clustering techniques are used in energy consumption in WSN. The soft-k means algorithm does not work with the large –scale wireless sensor networks, therefore it causes reliability and energy consumption problems. To overcome this, the proposed Load-Balanced Clustering conjunction with Coyote Optimization with Fuzzy Logic (LBC-COFL) algorithm is used. The main objective is to perform the lifespan by balancing the gateways with the load of less energy. The proposed algorithm is evaluated using the metrics such as energy consumption, throughput, central tendency, network lifespan, and total energy utilization.

Keywords: Clustering; wireless sensor networks; fuzzy logic; energy efficient; optimization

1 Introduction

Internet of Things (IoT) is used to assist the networking with billions of devices connecting together and also it collects and exchange the information for providing a variety of services. It is a communication network, which gains significance in the modern wireless communications [1]. Wireless Sensor Network (WSN) has generated a lot of interest in their hidden capacityand wide range of applications, for samples like, physical and environmental observation, monitoring of battlefield, security algorithms and disaster alignment [2]. A WSN includes numerous low-power sensor nodes that are generally non-uniformly deployed in the region of interest in order to monitor the events and collect data detected on the detection field. The technology of WSN is the core element on IoT, and it comprises of a collection of sensor nodes that are associated via wireless media. In IoT system, WSN plays an important part in collecting and sending the data to the network [3].

In the digital world, WSN and IoT play significant roles. There are many low-cost sensor nodes which are available in the WSN with a limited battery power supply. Usually, the sensor node is the small gadgets which are suitable for quantifying the a few events, for example, change made at a measurement such as temperature, pressure, weight, etc., or the element motion or of an detection of environment field. System with sensor node is consumable and is expected to last until to decrease their power. This makes scarce power in a commodity for that system and must be monitor to expand the sensor node life for the duration for performing strategy. In different applications, deployed nodes in random scenarios to watch and gather future of the physical condition of the surroundings such as humidity, temperature, pressure, location, vibration, and sounds, to name a few [4]. For further analysis and processing, the dataset is sent to the base station.

In WSN, there is an important challenges to reduce the power utilization, usually the sensor nodes are placed in unreachable places so that their batteries may not be rechargeable. In WSN, clustering is mainly used for the reduction of energy consumption over the networks. The clustering method groups the sensor nodes and forms separate clusters, with all nodes belonging to a single cluster. Every nodes detect its neighbouring surroundings and transmit the result to the Cluster Header (CH). Later the CH collects and processes the information. After that, information send to BS. Each node receive certain powers during process fetching and transmits the data, and finally dead node is defined [5,6]. it is critical for clustering algorithms to tackle WSN power consumption.

There are so many clustering methods that are used to design WSN with energy-efficient and extend their lifespan. In [7], it shows a CH selection method, which helps in the rotation of CH positions between higher energy nodes with various communication turns. In specific, the method takes into initial energy, the remaining energy and CH to finalize the next group of CH nodes in network.

Energy consumption is the major issues in the WSN. Soft-k means clustering algorithm which is used in the existing system. It does not work with large –scale Wireless Sensor Networks, therefore it provides reliability and energy consumption problem. To overcome this problem, the proposed system, Load-Balanced clustering conjunction with Coyote Optimization with Fuzzy Logic (LBC-COFL) algorithm were used. The contributions of the proposed system are as follows;

- ➢ Lifespan less-energy gateways are used in the balancing of the load.
- ➢ Proposed algorithm evaluates in the following metrics such as energy consumption, throughput, central tendency, network lifespan, and total energy utilization.

The article further is written with five sections: The Section 2 provides brief study on the existing Wireless Sensor Networks and Various clustering and Optimization methods. Section 3 has proposed working model. Section 4 evaluate the result and provides a comparative study on other algorithms. Section 5 gives a conclusion of the research work.

2 Related Works

In order to manage the network power and network lifespan, the clustering methods were used in the most efficient way. The hierarchical technique on clustering method comprises of separating all sensor nodes to form a group called clusters; there is a Cluster Head (CH) in each cluster and cluster members are declared as an enduring node [8–10]. CHs are the in chargers of meeting all the detected information from the cluster members and move to the Base Station in the cluster technique (BS). Furthermore, in the hierarchical cluster technique, CH node of choice procedure is an important job for improving the network power utilization, duration, throughput, and steadiness [11,12]. Because of the severe limits of the clustering problems in WSN [13,14], there is an increase in the number of researchers who are attempting to lengthen the network life and minimize the power consumption by creating meta-heuristic clustering algorithms.

The Fixed-Parameter Tractable (FPT) algorithm selects a gateway where each sensor node should be assigned to, resulting in the even distributed load and power utilization. Two questions has to be considered? What about a routing tree of the inter-cluster message that disperse routing overhead across all the nodes? The authors also suggested an FPT estimate technique with an estimate factor of 1.1 in [15], which is extra accurate than the prior estimate factors reported for Balanced Load based Clustering issues (LBCP). FPT methods are used to allocate the sensor nodes to the gateways while limiting the gateways' highest load. For power consumption of the nodes are balanced, an energy sensitive routing algorithm is utilized to find the ideal routing tree between the gateways and the sink. In [16], the same authors looked at an another FPT approximation technique with 1.1 of approximation factor. A virtual infrastructure of grid with many cells of equal size are employed so as to make the FPT access of algorithm more practicable in large-scale WSNs, with the FPT access method being executed independently in each group.

One of essentially considered areas in clustering is WSN [17]. The main purpose of routing protocol using clustering is effectively continue the dissipation of power using sensor nodes by assigning them in multi hop communications at clusters inside and by data collection implementation to reduce the information amount at base station. It is mainly due to minimize the range of communication among sensor node.

The cluster protocol is discussed in article [18] as namely Low Energy Adaptive Clustering Hierarchy (LEACH). Cluster head choice is performed randomly in network. The purpose of the cluster head in LEACH algorithm is arbitrary and CH task is to switch regularly between the nodes at the cluster. Therefore, CH selection with less power can easily fail and shorten network life. In LEACH based cluster, they uses a simulated annealing algorithm for recording optimal outcome with good location to reduce the energy dissipation of CH.

Adaptive periodic threshold sensitive energy efficient (APTEEN) sensor network is the next version of Threshold sensitive energy efficient sensor network (TEEN) [19,20], using all features. TEEN protocol helps to detect the signal. Further it quickly transfer the data to the source at any point. APTEE shared at fusion network and it records both the collection of periodic data and outcome to significant circumstances. The TEEN disadvantages is that values detected will not exceed the threshold, the communication is not happens at node while in APTEEN. The transmission of data with high delay and continuing transmission increase at edge.

In Short Distance Clustering (SDC) in the article [21], a sensor node added to cluster using gateway when the Euclidean distance is short. In the SDC created cluster, the average gateway power consumption is minimum; however, sensor node load of gateway is unbalanced. The SDC algorithm groups the nodes initially to consume less power, but later high power is consumed due to load of re-clustering. The SDC performance is experimented and outcome decreases with the number of clusters increasing.

Major concern is previous algorithms does not explore load balancing at node in clusters. To overcome this issue, article [22] proposed load balanced cluster algorithm (LBCA) to reduce power. For balancing load at system, the objective function is calculated using variance. The cluster communication consumes high energy by nodes. This makes research to look for next solution in article [23]. It proposes centralized load balancing with energy efficient computation algorithm (CELBA). Load balancing is highly efficient and minimizes power related problems. Here they suggest a objective function during cluster process. in article [24] distributed CELBA is used as DELBA. It is considered as better energy efficient technique than CELBA.

The objective of energy efficiency in WSN networks is a pressing one. Further research has been performed to increase the system evaluation in conditions of power utilization, throughput, load balancing, transmission costs, packet error rate, and latency in order to reach this goal. In order to process the enormous amounts of data, they have focused on the system connectivity and exchange the information. Both synchronous and asynchronous protocols have been proposed for the improvement of network connectivity in this research, each with its own set of benefits and drawbacks. Many academics have proposed so many approaches to increase the energy savings of the sensor node by modifying only a few properties of technologies.

Other research has looked into the load balancing problem in order to increase the energy efficiency by managing the network congestion and the data redundancy. When multiple sensor nodes are linked to the similar source transmit data at the same point of time, the data received by the source becomes clogged or fails, resulting in the reception of delayed sensitive data. In order to overcome the problem of data reception delay and reduced network power consumption, load balancing techniques are used [25]. WSN networks benefit from the cluster routing protocols because they reduce power consumption and improve the energy efficiency. This categorization of routing protocols yields four basic categories; usual, meta-heuristic, fuzzy, and hybrid algorithms [26,27].

In Wireless Sensor Networks, the energy consumption is the major problem. In the existing system, soft-k means clustering algorithm was used. It does not work with the large –scale wireless sensor networks, therefore it provides reliability and energy consumption problems. To overcome this problem, Load-Balanced Clustering conjunction with Coyote Optimization with Fuzzy Logic (LBC-COFL) algorithm were used in the proposed system.

3 Proposed LBC-COFL Methodology for Energy Efficient Computation

There are two types of nodes in the system; they are sensor nodes and gateways. The most important purpose of the gateway is to collect the data and then the base station gathers the data. Global communication is carried out over symmetrical connections; that is, a wireless connection among two nodes in the sensor is more efficient unless it is inside the communication areas apart from sensor nodes, gateways can communicate over vast distances, but they only within transmission range of each other. The proposed work uses the fuzzy logic system in the clustering method for improving the wireless network life span and reduces the energy utilization. The proposed system uses two models; they are Network model and Energy Model.

The architecture model Fig. 1 shows the process of COFL-LBCM methodology. Initially, the cluster head node is collected from the Wireless Sensor Networks, and then the algorithm is applied. It provides the desired output.

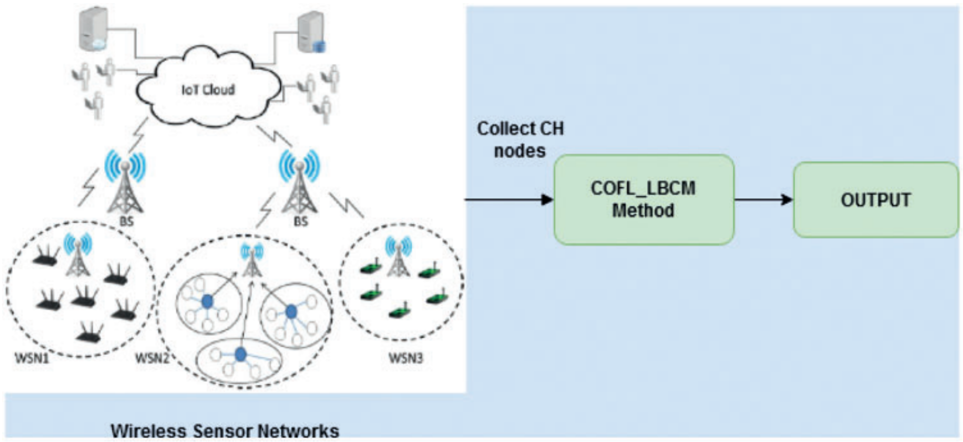

Figure 1: Architecture model of COFL-Load Balancing Clustering Method (LBCM)

3.1 Network Model

There is a group of sensor nodes in the network model randomly located in the area of the network, the size is N∗N. The nodes are motionless. Separate ID is given to each sensor and it correlates the information. From the environmental information, the sensor node is collected and the data is transmitted to their equivalent CH nodes. In terms of energy, all nodes are heterogonous. The BS is motionless and has enough energy and the location of the sensor node is well known.

3.2 Energy Model

The sensor node is changed because of the data transmission between transmit and receive states at a known time. It consumes power, during the sensor node of transmit or receiving the data, the transmitting and receiving node between the distance D. When D is small, free space transmission model (model D2) for a single jump transmission or a straight transmission is used, and when D is large, the multipath model (model D4) is used. Therefore, the power consumption takes place among the sender and the receiver by sending PS bits or packet from D.

$$\mathrm{EN}_{\mathrm{tp}} = \left(\mathrm{ß}_{\mathrm{t}}+\beta_{\mathrm{tamp}} * \mathrm{D}^2\right) * PS \tag{1}$$

$$\mathrm{EN}(_{\mathrm{PS,D)}} = \left(\beta_{\mathrm{tamp}*}\mathrm{D}^4\right) \tag{2}$$

Wherein the dimensions of the information packet is Play Station (PS) at the same time as EN represents the energy consumption keeping with bitv see in Eqs. (1) and (2). The tamp denotes the multipath energy version. The d0 denotes the threshold distance that controls or states whether to use “tamp or “fs. The calculation of d0 is shown in Eq. (3):

$$d0 = \frac{\sqrt{EN}}{\beta tamp} \tag{3}$$

Algorithm 1: LBCM

```
Input: Initialize the parameters a, b, m, n
Output: Average Eucledian Distance for sensor node deployement
    1.    for a = 1 to m do \\ gateway count
                eucl_dist_gw_a = 0;
    2.    for b = 1 to n do \\ no. of sensor nodes
            eucl_dist_gw_a += eucl_dist(gw_a, s_b);
            gw_listed_b= (s_b, eucl_dist(gw_b, s_a);
          End
          avgr_eucl_dist_gw_a = eucl_dist_gw_b/n;
        End
\\ initialize load for gateway
    3. For a = 1 to m do
          LOAD the [gw_a] = as 0;
       End
\\ add nodes one by one into gateway
    4. LBF = Ceil(s_n/g_x);\\ sensor node is 'n' and gateway is 'k'
    for a = 1 to LBF do
       for b = 1 to m do
          If (gw_list_a(s_b) ∉ LOAD(gw_k)) then
             LOAD as [gw_b]+ = gw_List_a(s_b);
          End
          Else
             While (gw_list _b(++s_b) ∉LOAD[gw_a]) do
                   LOAD[gw_a]+ = gw_list_b(s_b);
             Break;
             End
       End
    End
End;
```

3.3 *Load Balance Clustering Algorithm (LBCM)*

The fundamental goal of LBCM is just to arrange the sensing units everywhere around ports as effectively as possible. By delivering electricity to sensor devices in communications with neighboring sites and distributing the workload among them, clustering improves system capacity to a high amount of nodes and increases lifespan of the network. Clustering is generated related to the cost of connectivity as well as the demand on the access points. During the initialization phase, gateways locate sensor network within its wireless range. These ports convey information that the classification algorithm has begun. The sensor networks respond by sending their positions and identities straight to the portals. Both numbers and positions of the sensor network within every gateway's transmission network are stored in its database.

Every gateway estimates the average Euclidean range of the edge devices connected with a gateways gwi throughout the clustering phase. The rise in the sequence that their mean Euclidean distance is the manner wherein the portals start to connect the sensors networks of its clusters. In progressive order of Euclidean distance, the gateways gwi inserts sensor network out of its group. Each port should guarantee that network size linked with each clusters is below or equivalent to LBF while joining them to respective clusters. Such process is repeated until there is no more un-grouped number of nodes. A quantity of un-grouped sensor network corresponds to the number of sensors nodes at first. Because when grouping procedure is done, the clusters ID is sent to all sensor devices, so each clusters is designated to it as a sensor network. Every information is transmitted again through ports throughout inter-cluster communications.

3.4 Coyote Optimization with Fuzzy Logic

The important problem in WSN is to balance the power consumption in the network and also it helps to expand the network life. In this section, it works with the latest steady and energy-efficient cluster methods for WSN; called COFL algorithm, it is based on Fuzzy Logic and COA algorithms. The COA set of rules has demonstrated the technical troubles in lots of regions of research; that the COA attains quick, easy with strong union than the different methods. In electric transformers, the COA has the strength and balance to categorise the perfect gold standard parameters into single-section and three-section transformers. The outcomes suggest the performance and consistency of the proposed COA that calculates the correct version of transformers in comparison to the different optimization methods. There is a set of rules in COA with solved trouble of optimizing the identity of parameters of sun cells and distinct PV modules, in which the carried out COA has achieved better values over the alternative optimization set of rules.

3.5 Proposed COFL-LBCM Methodology

The important problem in Wireless Sensor Network (WSN) is to maintain the energy consumption in the network and also extending the network life. In this segment, a new constant and low-energy clustering technique is proposed or WSN called COFL-LBCM algorithm, based on COFL and Load-Balanced Clustering Method. In the proposed algorithm, COFL-LBCM provides a valid result in a practical time.

3.5.1 Phases of COFL-LBCM

COFL-LBCM algorithm has three main phases. In the first phase, it runs the Fuzzy Logic system trying to choose the temporary CH nodes. The fuzzy logic system output is used as an input of the second phase, for COA algorithm, the first population solution which improves the process of choosing the appropriate node CHs obtaining an optimal clustering process. The third phase is used in the reduction of energy consumption. COFL-LBCM of the flow organization is shown in Fig. 2. It consists of three phases; Fuzzy logic system, COA phase and LBCM phase.

3.5.2 Phase I: Fuzzy Logic System (FLS)

The initial set of CHs is chosen in this phase for fuzzy logic system. There are three parameters that are used for the selection of CHs; Residual Energy (RD), Distance to BS and Node Density. In the fuzzy logic system, these parameters are used as an input and then the probability is calculated. For calculating the probability, some fuzzy logic with if-then rules is used, and then the higher possibility nodes are used to assign the CHs.

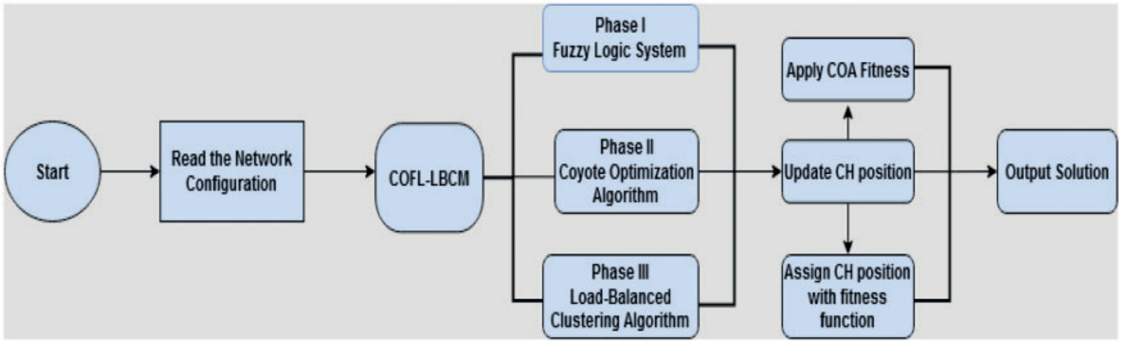

Figure 2: COFL-LBCM flow structure

3.5.3 Phase II: Coyote Optimization Algorithm

In the first set, the result of CHs is placed in the early population of the COA to express the methods in order to find an improved result than the one acquired in the initial step. In COA, the packs are defined as clusters, the coyote is defined as the usual node, and then alpha is depicting as cluster head node.

The solution terminals are tested. If the limits be exceeded at, origin to a recent puppy is given over again. Then the endurance weight of the puppy is calculated. The endurance weight among the puppies is lower than the elder one, and the puppy also stays alive. Otherwise, the puppy will be expired. Then the best value of t in the coyote is selected. The coyote is tested when the pack gets exit and one more pack is gone through according to P_{leave}. Then the package information is modernized.

3.5.4 Phase III: Load-Balanced Clustering Method

Its fundamental goal of LBCM is to arrange the sensing units from around ports as effectively as possible. By delivering electricity to sensor network in communications with neighboring sites and distributing the demand among those, grouping enables system capacity to a high amount of nodes and increases system lifetime. The groups are selected depending on the transaction cost and the capacity on the ports. During the startup process, ports locate sensor network are within its communication range. These ports deliver a message that the classification algorithm has begun. The sensor networks respond by sending their positions and identities straight to the portals. Both identities and positions of the cluster heads within every gateway's distribution networks are stored in its database. This links to phases II and III and gives the best results. COFL-LBCM algorithm is described in algorithm 2.

Algorithm 2: COFL-LBCM

Input: Collect the CHs, Sensor nodes.
Output: Best coyotes CHs
1: Start
2: Network Config is read
\\ Phase I: The fuzzy logic system is running
3: Input parameters are defined RE, DB, and ND in the Fuzzy Logic system.
4: Based on rule based, FLS is executed . . .

(Continued)

Algorithm 2: Continued

5: The probability is returned
\\ Phase II: The COA algorithm is running
6: NP pack, NC coyote and the maximum iteration is initialized.
7: Alpha coyote pack is defined.
8: Update the coyote position and evaluate the coyote position
9: End
10: New and old coyotes are developed
11: End While
\\ Phase III: LBCM algorithm
12. Call Algorithm 1
13: Update new positions
14: Output: best coyotes (Best CHs) are returned.

Algorithm 2 works with three phases; finally, it provides the best coyote CHs. It reduces the energy consumption while using the proposed system.

4 Result Evaluation

The evaluation result of the proposed COFL-LBCM method uses many relative parameter metrics such as alive nodes, network energy utilization, throughput of the system, standard deviation, and communication energy. The proposed algorithm reduces the communication costs, provides reduced energy consumption and provides more reliability.

4.1 Evaluation Based on Number of Alive Nodes

The evaluation among the amount of rounds and the quantity of alive nodes are tested, the alive nodes loss rate per round is given. There are three scenarios that are compared s1, s2 and s3. The amount of alive nodes every round in each scenario demonstrates the COFL-LBCM system's supremacy.

Fig. 3 shows the algorithms such as soft k-means and COA lose 85% of the nodes after few rounds, at 900 and 1400 rounds respectively. The proposed COFL-LBCM algorithm gives the minimum loss rate.

The network lifespan in the COFL-LBCM algorithm is high when compared to the existing algorithms, the COA and Soft k-means unsuccessful to extend the network lifespan. Therefore, comparing with the traditional algorithms, the proposed system has achieved high network lifetime.

Figs. 3–5 show the COFL-LBCM on the scenarios, in which s3 achieves 190 nodes in 3500 rounds compared to s1 and s2. Moreover, COFL-LBCM provides a helpful outcome on the stability of system.

4.2 Evaluation Based on Energy Consumption

The network nodes in the energy utilization are improved in each of the methods because the wide variety of turns has improved. The end result suggests the strength intake of the COFL-LBCM techniques which decrease than that of the diverse techniques. The proposed set of rules has decreased strength intake.

From the Fig. 6, it is observed that the proposed COFL-LCBM algorithm has consumed 94.75% of energy in 4000 rounds; therefore, it has less energy consumption, compared to the other algorithms.

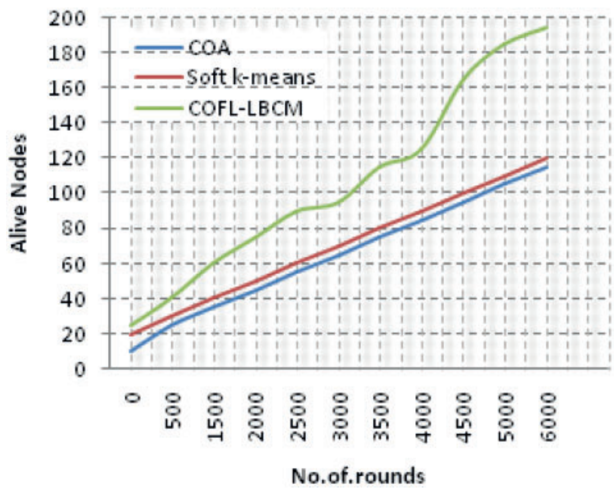

Figure 3: Loss rate of the alive nodes in case of s1

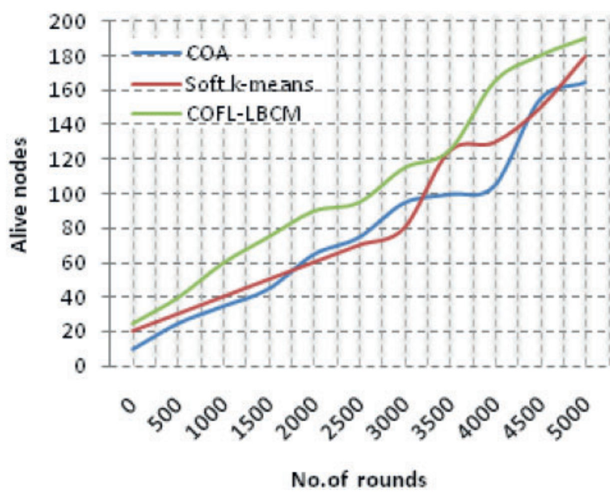

Figure 4: No. of alive nodes in case s2

4.3 Throughput of the Network

An enhanced power utilization is one of the major improvements. The total amount of data packets is received from BS out of the whole amount of turns. Thus, the proposed COFL-LBCM algorithm increases the throughput.

4.4 Standard Deviation

Modifying the number of sensors form 100 to 800 determines the standard deviation of every gateway's workload. During testing, the amount of gateways is constant, which are 10 in just this instance.

From the Fig. 7, it is observed that the proposed system has increased standard deviation of load with sensors and gateways. The proposed method has more scalability and also has linear increase in the gateways.

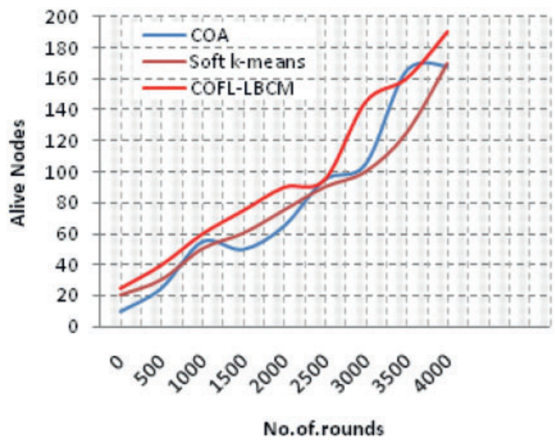

Figure 5: No. of alive nodes in case s3

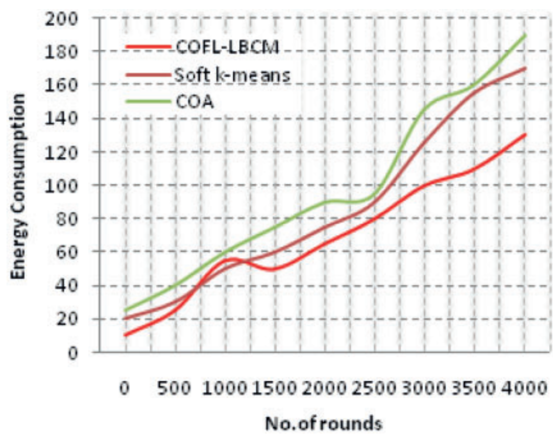

Figure 6: Energy consumption

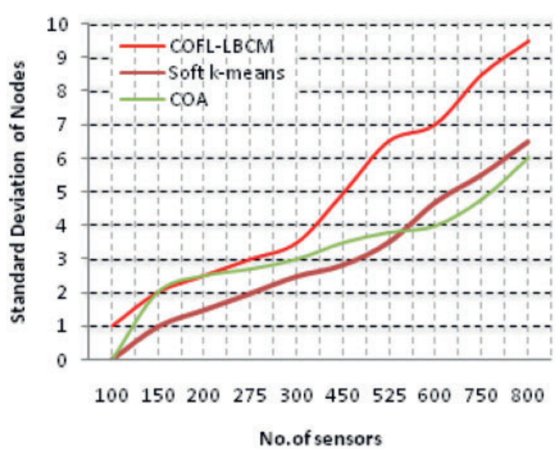

Figure 7: Standard deviation

5 Conclusion and Future Work

For energy-efficient Wireless Sensor Networks using many routes, the COFL-LBCM approach is presented to clustering the sensing nodes distributed across lower-energy gateways and distributes the loads on the sensing nodes amongst these portals. The gateway serves as intermediate nodes for data transmission from sensing nodes in the network. The clustering generated has an imbalanced load if the sensor networks are not uniformly spread throughout the ports, which will damage the service's longevity and energy usage. A suggested method's calculation was linked to performance measures such as living nodes, power usage, available bandwidth, standard deviation, and transmission power. In terms of energy efficiency and sensor node lifetime, the suggested COFL-LBCM method effectively provides a distributed amongst the various clusters and outperforms similar methods. It lowers the communications expenses while also lowering power usage and increasing dependability.

Acknowledgement: The authors would like to acknowledge the support of Prince Sultan University for paying the Article Processing Charges (APC) of this publication.

Funding Statement: The authors extend their appreciation to the Deanship of Scientific Research at King Khalid University for funding this work under grant number (RGP 1/282/42). Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2022R203), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

[1] B. Zhu, E. Bedeer, H. H. Nguyen, R. Barton and J. Henry, "Improved soft-K-means clustering algorithm for balancing energy consumption in wireless sensor networks," *IEEE Internet of Things Journal*, vol. 8, no. 6, pp. 4868–4881, 2020.

[2] A. Mohamed, W. Saber, I. Elnahry and A. E. Hassanien, "Coyote optimization based on a fuzzy logic algorithm for energy-efficiency in wireless sensor networks," *IEEE Access*, vol. 8, pp. 185816–185829, 2020.

[3] H. Ahmad and N. Kohli, "LBCM: Energy-efficient clustering method in wireless sensor networks," *Engineering and Applied Science Research*, vol. 48, no. 5, pp. 529–536, 2021.

[4] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand *et al.,* "I-SEP: An improved routing protocol for heterogeneous WSN for IoT-based environmental monitoring," *IEEE Internet of Things Journal*, vol. 7, no. 1, pp. 710–717, 2019.

[5] F. Deng, X. Yue, X. Fan, S. Guan, Y. Xu *et al.,* "Multisource energy harvesting system for a wireless sensor network node in the field environment," *IEEE Internet of Things Journal*, vol. 6, no. 1, pp. 918–927, 2018.

[6] S. Maheswaran, P. Kuppusamy, S. Ramesh, T. Sundararajan and P. Yupapin, "Refractive index sensor using dual core photonic crystal fiber–glucose detection applications," *Results Phys*, vol. 11, pp. 577–8, 2018.

[7] L. Xu, R. Collier and G. M. O'Hare, "A survey of clustering techniques in WSNs and consideration of the challenges of applying such to 5G IoT scenarios," *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1229–1249, 2017.

[8] A. Sarkar and T. S. Murugan, "Cluster head selection for energy efficient and delay-less routing in wireless sensor network," *Wireless Networks*, vol. 25, no. 1, pp. 303–320, 2019.

[9] Q. Wang, D. Lin, P. Yang and Z. Zhang, "An energy-efficient compressive sensing-based clustering routing protocol for WSNs," *IEEE Sensors Journal*, vol. 19, no. 10, pp. 3950–3960, 2019.

[10] M. Shanmugam, S. Nehru and S. Shanmugam, "A wearable embedded device for chronic low back patients to track lumbar spine position," *Biomedical Research*, vol. 29, pp. 1–12, 2018.

[11] N. Shivappa and S. S. Manvi, "Fuzzy-based cluster head selection and cluster formation in wireless sensor networks," *IET Networks*, vol. 8, no. 6, pp. 390–397, 2019.

[12] I. Daanoune, A. Baghdad and A. Ballouk, "An enhanced energy-efficient routing protocol for wireless sensor network," *International Journal of Electrical & Computer Engineering*, vol. 10, no. 5, pp. 87–93, 2020.

[13] S. Kaur and R. Mahajan, "Hybrid meta-heuristic optimization based energy efficient protocol for wireless sensor networks," *Egyptian Informatics Journal*, vol. 19, no. 3, pp. 145–150, 2018.

[14] N. AN, "Novel bacteria foraging optimization for energy-efficient communication in wireless sensor network," *International Journal of Electrical & Computer Engineering*, vol. 8, no. 6, pp. 2088–2097, 2018.

[15] R. Yarinezhad and S. N. Hashemi, "Increasing the lifetime of sensor networks by a data dissemination model based on a new approximation algorithm," *Ad Hoc Networks*, vol. 100, pp. 102084, 2020.

[16] R. Yarinezhad and S. N. Hashemi, "Solving the load balanced clustering and routing problems in WSNs with an fpt-approximation algorithm and a grid structure," *Pervasive and Mobile Computing*, vol. 58, pp. 101033, 2019.

[17] M. Zhao, Y. Yang and C. Wang, "Mobile data gathering with load balanced clustering and dual data uploading in wireless sensor networks," *IEEE Transactions on Mobile Computing*, vol. 14, no. 4, pp. 770–785, 2014.

[18] W. B. Heinzelman, A. P. Chandrakasan and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communications*, vol. 1, no. 4, pp. 660–670, 2002.

[19] D. P. Agrawal and A. Manjeshwar, "A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," in *Proc. Int. Conf. on Power Systems (ICPS)*, Lauderdale, FL, USA, vol. 3, pp. 0195b–0195b, 2002.

[20] A. Manjeshwar and D. P. Agrawal, "Teen: A routing protocol for enhanced efficiency in wireless sensor networks. in null," *IEEE*, *30189a*, 2001.

[21] G. Gupta and M. Younis, "Load-balanced clustering of wireless sensor networks," in *Proc. IEEE Int. Conf. on Communications(ICC)*, AK, USA, vol. 3, pp. 1848–1852, 2003.

[22] Y. Zhang, X. Zhang, S. Ning, J. Gao and Y. Liu, "Energyefficient multilevel heterogeneous routing protocol for wireless sensor networks," *IEEE Access*, vol. 7, pp. 55873–55884, 2019.

[23] A. Fanfakh, J. C. Charr, R. Couturier and A. Giersch, "Energy consumption reduction for asynchronous message-passing applications," *The Journal of Supercomputing*, vol. 73, no. 6, pp. 2369–2401, 2017.

[24] H. El Alami and A. Najid, "ECH: An enhanced clustering hierarchy approach to maximize lifetime of wireless sensor networks," *IEEE Access*, vol. 7, pp. 107142–107153, 2019.

[25] M. Adil, R. Khan, M. A. Almaiah, M. Binsawad, J. Ali *et al.,* "An efficient load balancing scheme of energy gauge nodes to maximize the lifespan of constraint oriented networks," *IEEE Access*, vol. 8, pp. 148510–148527, 2020.

[26] Q. Ni, Q. Pan, H. Du, C. Cao and Y. Zhai, "A novel cluster head selection algorithm based on fuzzy clustering and particle swarm optimization," *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 14, no. 1, pp. 76–84, 2015.

[27] N. Zaman, T. J. Low and T. Alghamdi, "Energy efficient routing protocol for wireless sensor network," in *Proc. 16th Int. Conf. on Advanced Communication Technology*, PyeongChang, Korea, pp. 808–814, 2014.