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Improved LEACH Protocol based on Moth Flame Optimization Algorithm for Wireless Sensor Networks

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Abstract - Wireless sensor nodes are made up of small electronic devices designed for detecting, determining, and sending data under severe physical conditions. These sensor nodes rely heavily on batteries for energy, which drain at a quicker pace due to the extensive communication and processing tasks they must carry out. Managing this battery resource is the major challenge in wireless sensor networks (WSNs). This work aims at developing an improved performance and energy-efficient low-energy adaptive clustering hierarchy (IPE-LEACH) that can extend the lifespan of networks. This paper proposes a novel LEACH protocol that uses the moth flame optimization (MFO) algorithm for clustering and routing to increase the longevity of the sensor network. IPE-LEACH proved to have a better cluster-head (CH) selection technique by eliminating redundant data, thereby extending the network lifetime. IPE-LEACH was compared with four other existing algorithms, and it performed better than: original LEACH by 60%, EiP-LEACH by 45%, LEACH-GA by 58%, and LEACH-PSO by 13.8%. It can therefore be concluded that IPE-LEACH is a promising clustering algorithm that has the potential to realize high flexibility in WSNs in case the CH fails.

Keywords/Index Terms— Wireless sensor network, Network Lifespan, Moth Flame Optimization, Cluster-head, Particle Swarm Optimization.

1. Introduction

Wireless sensor network (WSN) is a hot research area in the field of computer science and engineering, and they possess a wide area of application that includes but is not limited to computing and communication (Hadjidj *et al.*, 2013; Rohini *et al.*, 2022; Ouni & Saleem, 2022). The WSNs are a collection of various tiny sensor nodes. These nodes have the capacity to handle and exchange information so that they can act or collaborate with one another and employ wireless connectivity to carry out some duties (Rault, Bouabdallah & Challal, 2014). The protocol used for routing governs the transport of network data. As a result, the construction of a suitable network system is inextricably linked to the routing protocol (Ayoob *et al.,* 2016). WSNs are integrations of low-energy, low-cost sensor hardware, known as a sensor node, distributed throughout a sensor field. The number of sensor nodes that comprise a wireless sensor network can range from hundreds to thousands, depending on the application (Jondhale *et al.,* 2022). Possible applications include the military (monitoring friendly forces, battlefield, nuclear attacks, battle damage assessment, and the status of their troops). WSNs have been the subject of much research in the farming, automobile, space, and ecological (flood detection) fields over the past few decades (Corn and Bruce, 2017; Akyildiz *et al.,* 2002; Fascista, 2022; Ayaz, 2019). With a large application in the fields of medical assistance, logistics management, military operations, agriculture, environmental monitoring, and other related fields, WSN has become one of the most advanced technologies in the areas of telecommunication and computer exploration (Upadhyay, Kumar & Tiwari, 2015).

Moth flame optimization is a bio-inspired swarm optimization approach that centers on moths' movement behaviours near flames (Mirjalili, 2015). Moths, by nature, keep a stable angle with the moon while traveling, resulting in a straight-line journey. When an outside source of light, such as a flame, is brought near the moth, this is disrupted (Adamu, Dada & Joseph, 2021). The moth then begins to fly in circles while keeping a stable angle with the flame, eventually dying when it touches the flame.

Wireless sensor nodes, which are often battery-powered, serve the purpose of identifying and gathering data in locations where manual handling of battery replacement or recharging is limited. We must regard energy consumption as a crucial problem for detecting nodes in the network for it to perform efficiently and last longer (Goyal *et al.,* 2016). Many challenges still exist in the design and implementation of wireless sensor networks. Some of the most significant design issues in the WSNs include, but are not limited to, energy, self-management, security, routing, latency, signal fading, coverage, and others (Živković, 2014; Fahmy & Fahmy, 2020). The LEACH protocol dissipates more energy in transmitting data than any other component; to solve the energy consumption in transmission, this paper introduces some areas for improvement. The contributions of this work can be summarised as follows:

- introduction of a new LEACH protocol using moth flame optimization (MFO) that reduces the energy consumption by the cluster heads (CH).

- development of a cluster-head selection process that increased the lifespan.
- a simulation of a cluster-head that can resign from cluster-head and become a normal sensor so that it sends more rounds of data before it completely dies was done.
- the performance comparison of the proposed system with some selected algorithms was done using different network performance metrics.

The remainder of this paper is structured as follows: Section 2 discussed the related works. Section 3 is the methodology. And section 4 presents the results and discussions. While section 5 is the conclusion.

2. Related Works

Alrubaye & Myderrizi (2023) proposed the improved cluster head selection process in LEACH for minimizing energy consumption in wireless sensor networks (IV-LEACH) protocol to ensure an even distribution of selected cluster heads of motes over the network to increase the efficiency of the LEACH protocol. The IV-LEACH protocol outperforms the LEACH protocol, but a major setback is that random selection of cluster heads (CH) leads to CH with low residual energy.

Asvial, Admaja & Laagu (2023) developed the division non-cooperative game LEACH routing strategy is provided, which adapts a technique that utilizes low energy adaptive clustering hierarchy (LEACH) by distributing CHs. The allocation and decision-making steps are carried out by splitting the nodes' sensor fields into parts. The belief value achieved by the approach is based on the residual lively sensor nodes and total residual energy, as well as the energy needed for communication.

Padmageetha, Pramod & Mallanagouda (2023) implemented a new clustering protocol, the low energy data centric algorithm (LEDCA), for WSNs to reduce energy consumption and prolong the network life span of the WSNs. The sensing nodes collect data on demand; however, the hopping mechanism on sensor nodes generates energy for the remaining energy to supervise the time to maintain energy in each node.

Wang, Peng & Huang (2019) proposed a new approach in which rather than the bargaining method, they employ a time-sensitive contest strategy in their routing protocol to pick cluster head nodes to limit the constantly changing topology of messages being broadcast among sensor nodes. The modified routing protocol is more stable, which reduces the overall power usage of a WSN with lower transmission workloads and increases network longevity. The main disadvantage is that when it applies to real-world use, the outcome is not optimal due to the significant error range. It is brought about by unpredictable electromagnetic radiation. This is caused by elements such as surroundings, geographic position, obstructions, and so on. So, the next step will be to investigate and enhance distance measurement techniques to enhance the real-world value of the essential algorithms in the study.

Rafi, Ali & Akram (2019) applied an enhanced version of the leach protocol in a cloud environment to optimize power energy utilization or consumption based on the shortest distance or path selection. Furthermore, the proposed architecture integrates load distribution by selecting a fitting cluster-head node among its options based on their traffic status with the base station, sink, or cloud. Furthermore, they use a fog computing model for their case to extend the longevity of the wireless sensor network, in contrast to the initial approach to implementing the basic protocol. The proposed system, when compared to the traditional LEACH protocol, enhanced the network's effectiveness and overall strength. Furthermore, the outputs showed that the installation of the fog nodes and base station had an important impact on extending the longevity of WSNs.

Khan & Islam (2019) proposed a two-phase, energy-efficient, balanced clustering algorithm that will stabilize the load on the network. They considered the variables latent energy, and other factors. They evaluated their suggested method against CH-leach, a contemporary clustering protocol. The recently presented technique's simulation results produce improved load balancing, enhanced network longevity with energy equilibrium clusters, and a reduced node death rate. The limitation of their technique is that it suffers from an inability to escape being trapped in the local optima.

Behera *et al.* (2019) proposed a novel cluster head selection mechanism for WSNs. Simulation results show that the proposed system outperforms the LEACH protocol by improving throughput. The setback is that the algorithm does not consider time synchronization. Pandey, Rajan & Nandi (2018) described the moth flame optimization (MFO) algorithm for boosting the longevity of the sensor batteries. The proposed algorithm works better on mobile base stations. Moreover, with the assistance of this technique, the consumption of energy and the loss of packets can be reduced. It is also proposed that utilizing effective load distribution will boost the lifespan of networks.

Chen *et al.* (2018) proposed an optimization technique utilizing LEACH. Some nodes in the immediate area of the central station communicate directly with the base station. They improve its lifespan by boosting the energy consumption of the base station. After the cluster is established, they choose a secondary cluster head from the cluster. The secondary cluster head collects information and passes it to the base station. The drawback of the proposed method is that it consumes a lot of energy.

Zhixun, Yuanyuan & Yunfei (2022) developed a system that incorporates the qualities of the genetic algorithm (GA) with high speed of convergence and creates the GA-LEACH algorithm to address these challenges. The Chameleon algorithm performs LEACH clustering. Then, to choose cluster heads, use a GA. The outcomes of the simulation indicate that the challenges of unsuitable topological design and sluggish algorithm convergence in wireless sensor networks triggered by the selection of fair chance cluster heads have been successfully addressed. The limitation of the technique is that it consumes much energy.

Mohammed *et al.* (2022) developed a

novel approach to address some of the LEACH protocol's shortcomings. The proposed method divides the communication region into segments to reduce the length of transmission and thus the total consumption of energy. The outcomes demonstrate a reduction in overall spent energy and an increase in network lifespan when compared to the original LEACH and the other techniques compared in the study.

Al-Otaibi *et al*. (2023) applied the K-medoids were developed using sunflower-based segmentation and an inter-layer-based optimal navigation technique. The CH is chosen using an effective fitness parameter derived from various targets. Sunflower optimization (SFO) determines the optimal communication line to the node serving as the sink after CH choice. The proposed protocol outperformed the other protocols compared in the study. The suggested system has a disadvantage in that the sensor hub consumes more energy under certain conditions and has a slower rate of packet delivery.

Li *et al*. (2017) proposed an ant colony optimization (ACO) for an energy-effective wireless sensor network. The approach reduced the unused energy as well as the gap between neighboring nodes. As the length between nodes was evaluated, the next hop was adjusted based on the pheromone level. The proposed approach demonstrated that an energy-saving node was not chosen as the next hop, resulting in an effective load distribution of energy consumption in the network.

Taj & Kbir (2016) proposed a more effective multipath leach protocol that employs only one transitional cluster head. The protocol's goal is to increase the network's longevity and transfer greater amounts of information than the initial protocol. Each time, this program produces a packet and delivers it to the bottom tier. Results show that their approach enhances the quantity of transferred packets and improves the lifespan of the network. The work's disadvantage is that the effectiveness of the suggested system cannot be determined because it was only compared to LEACH.

Cai *et al*. (2020) proposed a unified heuristic bat algorithm (UHBA) for optimizing the choice of cluster head. The technique ensures that cluster head selection can flexibly alter both global and local searches. At the same time, when compared against various other forms of the bat algorithm, the outcomes show that the algorithm performs better. Furthermore, the algorithm performs better than other approach used in the paper. The limitation of the work is that the performance of UHBA-LEACH was only tested on benchmark functions and not in real-world scenarios.

Chithaluru *et al*. (2021) proposes an increasingly resilient Energy Enhanced Threshold Routing Protocol (ETH-LEACH) for WSNs. The operation of ETH-LEACH is divided into two components. In the initial section, TDMA is used to calculate dynamic pathways to reduce network latency. In addition, an acceptable limit is determined in the second section for selecting transmit nodes. The approach suggested brings down the energy utilisation level of sensor nodes, boosting the lifespan of the network by elongating the life span of dying nodes. The effectiveness of the approve needs to be improved.

Table 1: Summary of related works, contributions, and research gap.

Reference	Technique Used	Contribution(s)	Research Gap
Alrubaye & Myderrizi (2023)	IV-LEACH.	Better performance compared to LEACH protocol	Random selection of cluster heads (CH) leads to CH with quick depletion of left over energy.
Asvial, Admaja & Laagu (2023)	Non-cooperative game LEACH.	Improve performance compared to original LEACH.	Power consumption is still very high.
Padmageetha, Pramod & Mallanagouda (2023)	LEDCA.	Hopping mechanism on sensor nodes generates energy for the remaining energy to supervise the time to maintain energy in each node.	Need to further improve the lifespan of the CH nodes.
Wang, Peng & Huang (2019)	Improved unequal cluster-based routing protocol.	Increased stability, which lowers the general power usage of a WSN with lesser transmission workloads and upturns network prolonged existence.	The performance cannot be said to be optimal when it applies to real-world use, because of the significant error range.
Rafi, Ali & Akram (2019)	Enhanced low-energy adaptive clustering hierarchy leach protocol.	Optimize energy consumption based on the shortest distance or path selection in a cloud computing.	There is need to boost the lifetime of network.
Khan & Islam (2019)	Balanced clustering approach.	Better load balancing, greater network durability and a decreased node death rate	The approach experiences failure to escape being trapped in the local optima.
Behera *et al*. (2019)	Residual energy-based cluster head selection.	Outperforms LEACH protocol by increasing throughput.	The technique does not consider time synchronization.
Pandey, Rajan & Nandi (2018)	Moth flame optimization (MFO).	Outclasses LEACH protocol by enhancing throughput.	There is still need to enhance the lifetime of network by reducing energy

			usage.
Chen *et al*. (2018)	LEACH.	Improve network lifespan by boosting the energy consumption.	Consumes a lot of energy.
Zhixun, Yuanyuan & Yunfei (2022)	GA-LEACH.	Overcome the problem of unsuitable topological design and lethargic algorithm convergence.	It consumes much energy.
Mohammed *et al*. (2022)	S-LEACH.	Split communication area into parts to lower the length of transmission and overall energy consumption.	Energy consumption is relatively high.
Al-Otaibi *et al*. (2023)	Hybrid K-medoids and energy-efficient sunflower optimization algorithm.	Proposed system performed better than other protocols under comparison.	High energy Consumption by sensor hub and time-consuming rate of packet delivery.
Li *et al*. (2017)	ACO method.	Effective load distribution of energy utilisation in the network.	Network lifespan still need to be elongated.
Taj & Kbir (2016)	Multipath leach protocol.	Improvement in the number of broadcasted packets and the longevity of the network.	Performance was only compared with original LEACH protocol, so effectiveness cannot be ascertained.
Cai *et al*. (2020)	UHBA-LEACH.	Performs better than other variants of bat used with LEACH protocol.	Performance was only tested on benchmark functions and not in real-world circumstances.
Chithaluru *et al*. (2021)	ETH-LEACH.	Decrease in energy usage by the network and increase in network longevity.	There is need to further enhance the lifespan of the network.

3. Methodology

IPE-LEACH adopts the evolutionary nature of moth and designs a moth flame optimisation (MFO) algorithm for WSN design. Based on the moth's behaviour, it is possible to develop a network environment to control it. Also, cluster the sensor nodes into an optimized state. Thereby saving energy, aggregating data, and increasing network lifetime, which controls the power utilized by the sensor. Previously, Mirjalili (2015) formulated a metaheuristic algorithm sufficiently strong to simulate the hopping around of moths scientifically. Moths employ longitudinal rotation to travel at late hours, allowing them to walk in a straight line at a set angle with the moon's light.

However, while traveling in a transversal direction at an exact angle with the source of illumination, they end up in a circular motion, eventually coming together at the light source in a catastrophic meeting. The MFO approach presumed that the potential solutions are moths and that the parameters of the problem are the positions of the moths in space. As a result, the moths can move in one-dimensional, two-dimensional, three-dimensional, or hyperdimensional space by altering their trajectory coordinates (Mirjalili, 2015).

3.1 Setup Phase (Cluster Head Selection phase)

In this paper, the system operates in rounds like LEACH protocol (Bongale, Swarup & Shivam, 2017). There are two stages involved: the stable stage and the data transmission stage. Groups emerge with a cluster head node in the stable stage, then move to a data transmission stage in which each node sends data to CH nodes and CH to the base station according to a predefined TDMA frequency. In the LEACH protocol, a node n_i that wishes to get involved in cluster head selection creates an arbitrary number between 0 and 1, and if the produced number is less than the probability-based threshold T(n_i) value, as computed by equation (1), the node n_i is chosen as cluster head.

$$T(n_i) = \begin{cases} \dfrac{P}{1 - P * (r \, mod(1/P))}, & n_i \in N \\ 0, & otherwise \end{cases}$$

Where P represents the preferred proportion of cluster heads, r represents the present round, and N is the set of nodes that were not selected as cluster head nodes in the previous (1/P) rounds. However, LEACH has problems such as selecting the CH using a threshold value, irregular allocation of CHs, the likelihood of choosing a node with very little energy as the CH, and several more. T(n_i) is adjusted in IPE-LEACH as shown in equation (2).

$$T(n_i) = \begin{cases} \dfrac{P}{1 - P * (r \, mod(1/P))} * \dfrac{E_{n_i}}{E_{intial \, i_{avg}}} & n_i \in N \\ 0, & otherwise \end{cases} \qquad (2)$$

Where E_{n_i} is present energy of node n_i and $E_{intial \, i_{avg}}$ is the overall network's mean starting energy. Therefore, the energy parameter influences the probability-based threshold value T(n_i), which aids in determining the best CH nodes. Figure 1 depicts the EiP-LEACH cluster head selection. The proposed method functions similarly to the LEACH protocol. The main distinction between LEACH and the proposed approach is that the CHs are chosen primarily based on an energy-influenced parameter.

Every node n_i in the proposed technique builds an arbitrary number R_i $(0 < R_i \leq 1)$. Equation (1) depicts the change in $T(n_i)$ computation. If the random number $R_i < T(n_i)$ is generated, the node n_i is proclaimed the CH node for the present node, and CH sends an ADV signal to every node in the entire network, announcing that it is now the CH node and allowing additional nodes to come together with it to establish a cluster.

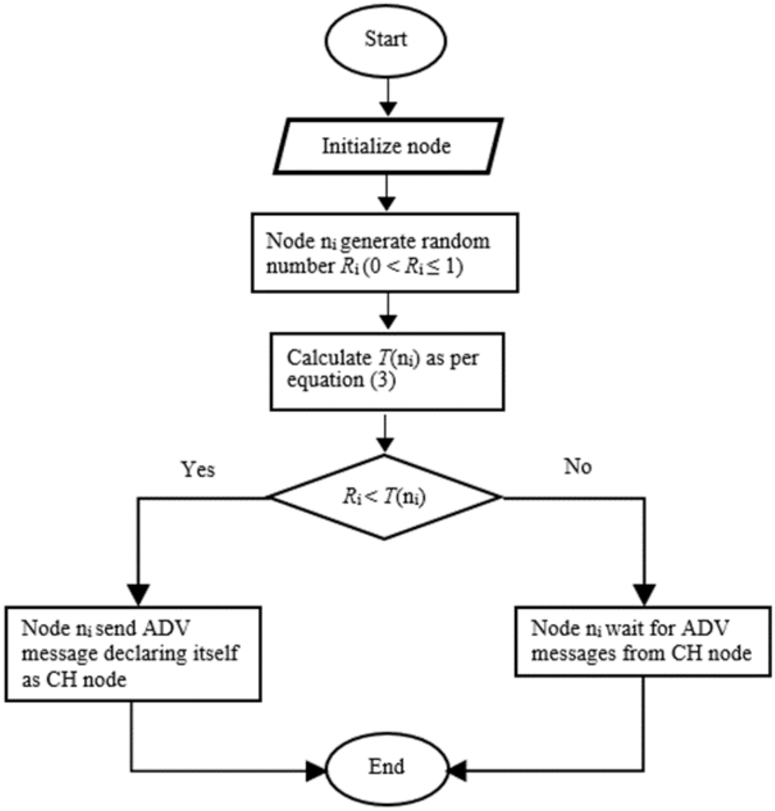

Figure 1 Cluster Formation Phase of IPE-LEACH

3.2 Steady State Phase

The data transfer process occurs during the steady state period. During this stage, the nodes in each cluster transfer data to their cluster heads according to the duration allotted for broadcast. To minimize the loss of energy, the receivers of every non-cluster head node were switched off for the duration specified by the nodes. The cluster head combines every bit of data supplied by each of the nodes into one signal and sends it to the central station after obtaining all the data from the nodes.

Suppose the total number of sensor nodes in the network "N" are distributed randomly in a 100 x 100-meter area, and the probability of becoming cluster head (CH) in the network is 0.1% (that means in every ten sensors, one becomes cluster head). It is believed that nodes are dispersed equally and haphazardly across a confined network area. It is additionally thought that these nodes are uniform, which implies that they have similar detection and communication capacities and share the same starting but restricted energy supply. It is also believed that the sinkhole is located some distance from the sensing nodes, yet each sensor node can transfer data immediately to the CH. It is also expected that CH receives data packets from its cluster members, combines the acquired data with its own, and then sends these data packets to the central station.

The model includes the following kinds of energy use variables: sensing, accumulation, dissemination, and reception. The frequency of energy used for detecting and creating one bit of data is represented by e_s, and the frequency of energy usage for accumulating one bit of data packet is depicted by e_a. When a node sends one bit, it uses e_t energy, and when it gets one bit, it uses e_r energy. In this study, a widely employed initial-order broadcast energy model (Ghasemzadeh *et al.*, 2014) is utilized, in which the use of energy is determined by the trajectory or distance traveled and is described by equation (3).

$$e_t(d) = \begin{cases} e_e \times \in_{fs} \times\ d^2,\ d < d_{th} \\ e_e \times \in_{mp} \times\ d^4,\ d \geq d_{th} \end{cases} \quad (3)$$

Where e_e is the electronics energy dissipation to run transmitter circuit, $\in_{fs}$ and $\in_{mp}$ represent the amplifier energy, which is determined by the distance d which is more than the borderline energy d_{th}, d is the gap between the transmitter and receiver. When d is less than $d_{th}(d_{th} = \sqrt{\in_{fs}/\in_{mp}})$, the free space model (fs) is used, whereas the multipath fading (mp) is used.

After cluster construction and TDMA creation, the algorithm's final stage, data transmission, begins. During this stage, each of the member nodes shuts down their radios and only uses them during their allotted broadcast period. The amount of energy consumed by each node is therefore reduced. Nevertheless, since individual nodes are sending data to them, cluster heads should always keep their receiver turned on during the data transfer stage. It is important to emphasize that LEACH nodes only broadcast data to their cluster heads.

3.3 Proposed IPE- LEACH Algorithm

Step 1: Place the sensor nodes in the appropriate environments.
Step 2: Split the environment into multiple clusters, each with the same or a distinct number of sensor nodes.
Step 3: Each sensor node in a cluster chooses a cluster head node (CH) for the cluster. The CH has more energy and battery capacity.
Step 4: Connect all sensor heads or cluster heads to the base station (BS). The

central station contains all the information about the sensor node and cluster head.

Step 5: The base station broadcasts the commercial message to all cluster heads in the wireless ecosystem.

Step 6: The signal is picked up by all cluster heads and forwarded to the sensor nodes in the cluster.

Step 7: Each sensor node delivers the response message to the cluster head.

Step 8: The response message is sent to the base station by each cluster head.

Step 9: Following that, transmission of data and messages will begin, and all sensor nodes will share information with CH.

Step 10: Process end.

4. Result and Discussion

The experimental approach of Kim *et al.* (2010), which investigated the impact of each node's starting energy, was adopted in this study to assess the impact of each node's starting energy in the initially developed LEACH, EiP-LEACH, LEACH-PSO, and the proposed IPE-LEACH protocols. According to the authors, the starting energy level in the study was set at 0.5. Here, we utilized the following metrics to analyse and compare the effectiveness of our approach: network lifetime, the number of cluster heads produced in each round, and packets transmitted.

The network lifespan is a significant consideration when analysing a sensor network. The lifespan of each sensor node that is an integral component of the network is what determines the network's longevity. In numerous instances, charging and changing the nodes' batteries is problematic. As a result, the scientific community is replete with various techniques aimed at extending network longevity. Dietrich and Dressler (2009) created several lifetime metrics. In the present investigation, network longevity is regarded as the time between the death of the initial node and the death of all nodes.

The number of rounds (every successful transmission of data from cluster head to base station is termed a round) in a network is denoted as r. The highest number of rounds used in this network is depicted by r_{max}. Table 2 shows various potential parameters. Where Eo is the amount of energy given to each node. Emp is the node's amplification energy, Efs is the energy used when data gets transmitted from the sensor node to CH, and Eda is the energy used during the data transfer latency. Etx and Erx represent the energy saved during data packet transfer and receipt. With these variables and nodes, network operation begins with the IPE-LEACH protocol to improve the following parameters:

1) Network lifetime and
2) Network energy consumption

4.1 Simulation and parameters

In this section, the simulation of IPE-LEACH and other protocols was performed to check their behaviour in terms of network performance, power conservation, and data packet transfer. A

MATLAB tool was used for simulating the original LEACH, EiP-LEACH, LEACH-PSO, LEACH-GA, and IPE-LEACH protocols performance using the Microsoft Windows 8x64 bit operating system and the Intel Core i5 third generation by considering several sensor nodes that are randomly distributed in a 100*100-ms area, as shown in Figure 2.

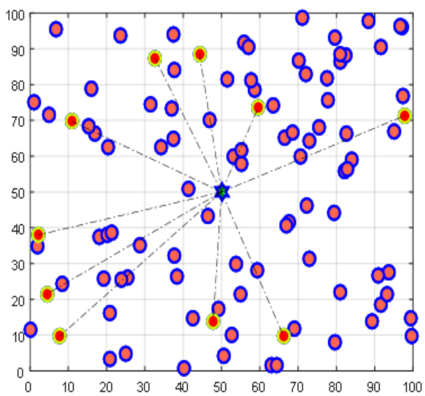

Figure 2 Sensor nodes randomly distributed.

Each sensor node sets 0.5 joules as the starting energy of the node, with a 0.1 likelihood of it being a cluster head (CH). Additional simulated parameters with specific corresponding values were also evaluated; desirable values of the simulated parameters are presented in Table 2.

Table 2: Network Parameters Used

Parameter	Value
The number of wireless sensor node	100
Energy transmitting circuit (E_{TX})	50nJ/bit
Energy transmitting circuit (E_{RX})	50nJ/bit
The original node energy (E_o)	0.5J
Energy utilisation of signal amplification under the available space of unit data (E_{fs})	10pJ/bit/m^2
Signal enhancement consumes energy for various path dampening of atomic data (E_{mp})	0.0013pJ/bit/m^4
Data fusion energy (E_{da})	50nJ/bit/message
Control packet length	100bits
Data message length	4000bits
Steady communication radius of nodes	15m
Maximum number of rounds (r_{max})	10000

The graph depicted in Figure 3 is an evaluation of network lifetime and average energy consumption as compared with four other protocols. The yellow colour line represents Original LEACH, the green colour represents LECH-GA, the black colour represents EiP-LEACH, the red colour represents

LEACH-PSO, and finally, the blue colour represents IPE-LEACH. Figure 3 demonstrates that, at the beginning of the network operation, Original LEACH records the poorest performance of the four protocols. The original LEACH starts declining alive nodes at 513, LECH-GA at 868, EiP-LECH at 1600, and LECH-PSO at 2472, while in IPE-LEACH, the collapse of the initial node happened at the 2600th round. As network activities progress, the number of dead nodes in the IPE-LEACH protocol is significantly lower in comparison to all the protocols evaluated. As illustrated in Figure 3, the four protocols record deaths for all nodes in 7239 rounds, whereas the IPE-LEACH protocol stretches it even more, resulting in an expansion of the network's longevity.

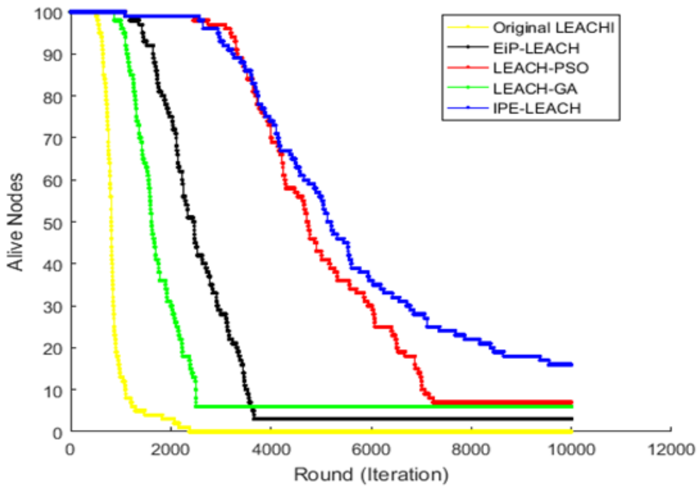

Figure 3 Network lifetime with number of alive nodes vs rounds (iteration)

The principal objective of WSNs is to transport data from nodes to BS. When the life expectancy of the network was extended, additional data would be detected and sent to the BS, thereby increasing network effectiveness. Figure 5 depicts the transmission of data packets in each of the five protocols. IPE-LEACH substantially outperforms the other four protocols, delivering around 9551 rounds to the BS, while Original LEACH delivered 2338 rounds, EiP-LECH gave 3665 rounds, LEACH-PSO delivered 7230 rounds, and LEACH-GA delivered 2505 rounds. However, the LEACH-PSO performs a little bit better at the beginning of the network. Each of the four protocols barely delivers packets of approximately 7230, demonstrating that they are unable to resist the newly suggested protocol, as depicted in Figure 4.

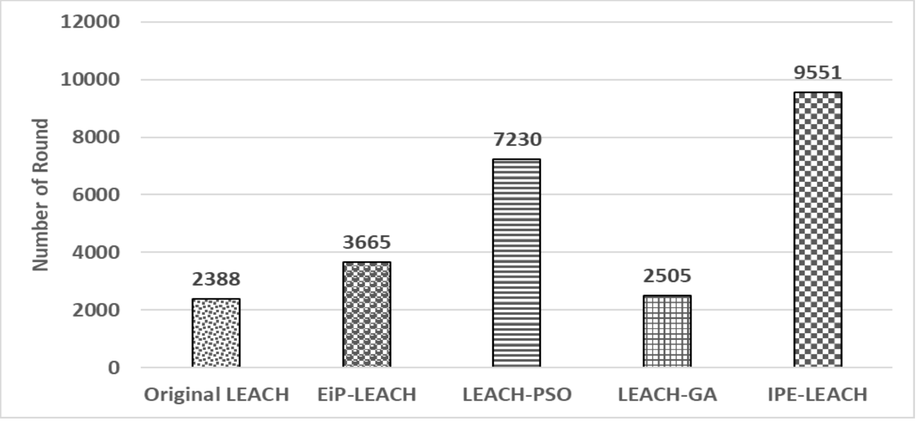

Figure 4 Comparison of the number of Rounds between five algorithms.

4.2 Network Energy Consumption

Figure 5 depicts the usage of energy throughout network activity. The graph illustrates that IPE-LEACH performed significantly better than the other four methods. IPE-LEACH consumes the least amount of energy for each number of rounds. IPE-LEACH used the smallest quantity of energy. This improves the percentage of nodes that are functional while also enhancing packet delivery proportion, network longevity, and efficiency, as illustrated in Figure 5. Different scenarios were considered during the experiments. Using five algorithms in each, the number of rounds and average energy usage by IPE-LEACH were compared with those of some other protocols. Experimental results indicated that the IPE-LEACH protocol uses less energy, which contributes to the sensor network's longer lifetime.

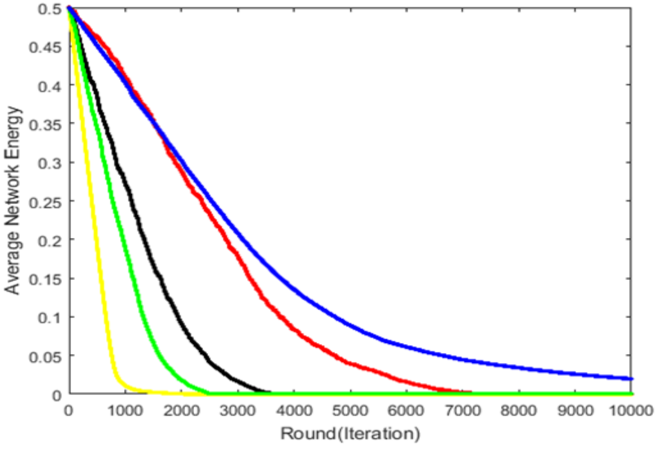

Figure 5 Average network Energy against the number of rounds

Table 3 depicts the statistical results of the simulations that was carried out. It can be seen from the results that the energy utilisation of IPE-LEACH is the lowest.

Table 3: Network Energy Consumption at different energy level

Energy (J)	Original LEACH	EiP-LEACH	LEACH-PSO	LEACH-GA	IPE-LEACH
0.4	164	443	1092	318	1093
0.3	327	844	1808	627	1990
0.2	491	1337	2704	972	2961
0.1	653	1927	3678	1308	4560
0	2388	5665	7580	2505	9551

Figure 6 shows the energy efficiency of the five algorithms under different energies for the nodes. The energy efficiency of the network of the IPE-LEACH is higher than that of the Original LEACH, EiP-LEACH, LEACH-PSO, and LEACH-GA algorithms with different energy levels, but the energy status of the LEACH-PSO is more than that of the IPE-LEACH between energy levels 0.35J and 0.5J. In general, the IPE-LEACH performs better considering the network lifetime.

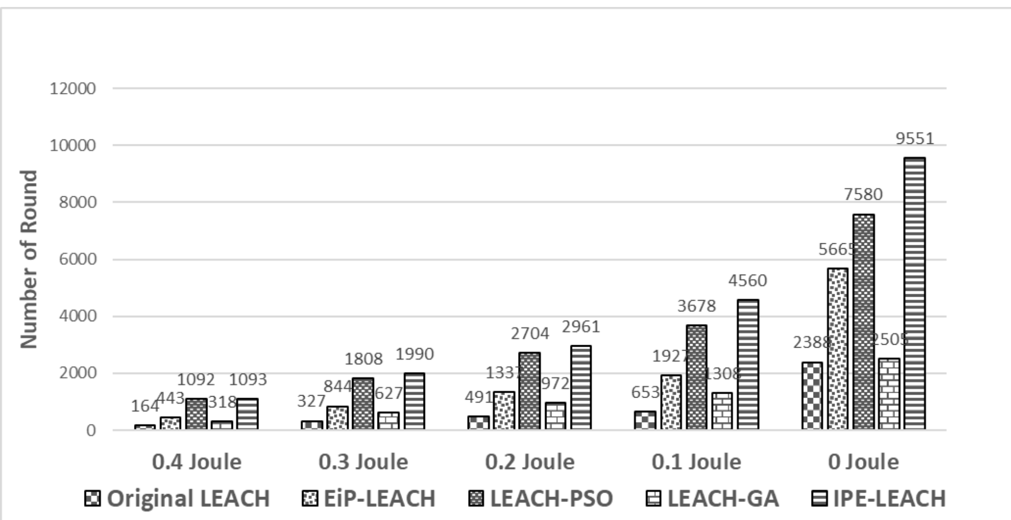

Figure 6 Network Energy Consumption

IPE-LEACH have surmounted the problem of lack of scalability in the original LEACH protocol. Also, the issue of absence of adaptability has been overcome. IPE-LEACH's parameters can be dynamically adjusted based on the circumstances of the network. Once the first cluster construction is complete, the protocol functions with set parameters for the duration of the network, regardless of modifications to node weight, energy consumption, or network activity. This ability to adapt will result in efficient energy use and acceptable network performance. While IPE-LEACH offers several advantages, it also has certain limitations, including:

1. Disparities in cluster creation: In every iteration, LEACH uses randomness to pick cluster heads. As a result, some nodes might get chosen as cluster heads more often than others, resulting in unbalanced energy usage throughout the network. This can lead to some nodes rapidly using up their energy, producing unpredictability in the network and shortening the entire network's lifetime.
2. Rigid choice of cluster head requirements: LEACH chooses cluster heads purely according to their energy threshold, without taking into account other essential aspects like node closeness to the centre station or energy left over after cluster head tasks. This overly simple choice strategy might lead to unproductive cluster head allocations and undesirable routing routes.
3. The absence of fault resilience: IPE-LEACH lacks integrated techniques for dealing with node downtime or alterations to the network topology. If a cluster head collapses or becomes inaccessible, the cluster may dissolve, requiring the entire network to go through the clustering procedure again. This inability to tolerate faults can lead to network outages and higher costs.
4. Lack of adequate safety procedures: IPE-LEACH lacks adequate defense measures to prevent various cyberattacks such as spying, tampering, and node spoofing. The lack of safety safeguards can expose IPE-LEACH to a variety of safety risks, jeopardizing the security and privacy of network data.

Conclusion

In this paper, a new algorithm has been applied, which is the MFO, for the improvement of the network lifetime of the LEACH protocol. Improvements have been made to minimize the energy wasted in routing the data packets sent by the nodes that are close to each other in a randomly deployed sensor network. The overall goal is to minimize energy consumption to maximize the network's lifetime. The proposed paper has been designed and implemented in the MATLAB application using the network simulation toolbox. The comparative analysis has clearly shown the effectiveness of IPE-LEACH using moth flame optimization.

IPE-LEACH was compared with four other existing algorithms, which include Original LEACH, EiP-LEACH, LEACH-PSO, and LEACH-GA, in relation to network life expectancy, energy usage, cluster-head selection, and cluster-head selection. It was found that IPE-LEACH is far better than original LEACH by 60%, higher than EiP-

LEACH by 45%, higher than LEACH-GA by 58%, and higher than LEACH-PSO by 13.8%. Given the entire network, the criteria, and the outputs achieved, it can be argued that IPE-LEACH outperformed all the other clustering techniques considered in this paper. IPE-LEACH can attain excellent adaptability in wireless sensor networks in the event of a BS breakdown.

Every design always has a scale of enhancement on which others might work. The study recommends that the same design can be implemented using a mobile base station. Further consideration would potentially also account for the mobility of the sensor nodes. Moreover, some other scenarios, such as the reformation of clusters after the death of a node or the entry of a new node into the system, could be considered in future work. Finally, this protocol is only used in the sensor area when there is BS. However, because the BS is located far away from the sensor region, we cannot use this protocol. In the future, the study will address node energy distribution when the BS is remote from the sensor region to boost the whole life expectancy of the network. More work will also be done using methods such as artificial neural networks (Dada, Yakubu & Oyewola, 2021), grey wolf optimisation (Dada *et al.*, 2022), and ensemble methods to verify their effectiveness in improving the network lifespan of the LEACH protocol.

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