International Journal of Communication Networks and Information Security
2024, 16(1), 6409
ISSN: 2073-607X,2076-0930
https://https://ijcnis.org/ **Research Article**

Energy Efficient Clustered Load Balanced LEACH Protocol Based on Particle Swarm Optimization in Underwater Wireless Sensor Networks

Poonam Dhankhar [1], Vikas Siwach [2], Harkesh Sehrawat [3]

[1,2,3] Maharshi Dayanand University, Rohtak, India
***Corresponding Author:** poonamdhankhar11@gmail.com

Citation: P. Dhankhar, V. Siwach, and H. Sehrawat, “Energy Efficient Clustered Load Balanced LEACH Protocol Based on Particle Swarm Optimization in Underwater Wireless Sensor Networks,” *International Journal of Communication Networks and Information Security (IJCNIS)*, vol. 16, no. 1, pp. 19-32, Apr. 2024.

ARTICLE INFO

Received: 15 November 2023
Accepted: 6 April 2024

ABSTRACT

Underwater wireless sensor networks (UWSN) are generally positioned over a sizeable aquatic area and sensor nodes are mobile due to their distinct environment. The networks' sensor nodes have the ability to self-organize and communicate. The sensor networks are used in many fields, such as habitat monitoring, small energy cost, object/entity tracking, forecasting and remote control of hazardous regions, surveillance, routing etc. Due to their mobility, sensor nodes use more energy, have a lower node distribution density, and require longer localization times. Clustering is an efficient topology control strategy for achieving the goal of conserving energy. This manuscript presents a novel technique for prolonging the lifetime of a network using the LEACH protocol. The proposed load-balanced LEACH protocol uses the concept of PSO (Particle Swarm Optimization) in which a cluster head is chosen based on UWSN's current energy level, load factor, degree of nodes, and distance from the head node are used for clustering to reduce energy consumption. The proposed design has been simulated in NS2.35 and compared with three clustering routing protocols, LEACH, E-LEACH, and C-LEACH on the various performance factors like remaining energy, number of packets transmitted and lost during transmission, bit-rate analysis, number of alive and dead nodes. The proposed design shows an improvement in network lifetime and in energy conservation by selecting optimal cluster heads.

Keywords: Base Station (BS), Cluster Head (CH), C-LEACH, E-LEACH, LEACH, Optimization, PSO Algorithm, UWSN.

INTRODUCTION

The Earth, on the other hand, is a planet of water, with water covering 70% of its surface. The underwater wireless sensor network is made up of a network of symbiotic underwater sensors or acoustic nodes connected by acoustic linkages. These sensor nodes detect, analyze, and transmit aquatic events to surface-based systems.

The clustering model's topology control is the most effective method for resolving the issue with UWSNs as it can balance energy consumption, extend network life, and eliminate communication interference. By using clustering, the entire UWSN is split up into different regions. Sensor nodes can only communicate with the head node of their cluster in every zone. Multilayer protocol architecture is required to transmit data to the base station. Sensor nodes need to capitalize on energy levels, team optimization, and other aspects, resulting in poor performance.

The current study is focused on designing an energy-efficient routing technique that may utilize data received by various layers. Although there are various theoretical applications for UWSN, technological constraints limit its practical application. Since the ocean rapidly absorbs a high-frequency signal and an optical signal is progressively lost due to refraction and reflection, sensor nodes are unsuitable for long-distance communication.

Due to the deployment of UWSN in complex environments and the low energy capacity of underwater sensor nodes, it is difficult and expensive to replace batteries to keep UWSN functioning properly [1].

The term "clustering routing" comes from a network having several groups or clusters. Every cluster has a tree-like structure comprising several leaders called cluster heads and members. The CH (cluster head) transfers the data collected by cluster members to the base station (BS) or another CH for fusion. The data composed by cluster member nodes are sent by the head node after fusion to reduce the amount of energy required by the network and prevent each cluster member node from sending data independently. In wireless sensor networks, clustering routing algorithms like LEACH, E-LEACH, and C-LEACH are frequently used.

The discrete PSO (particle swarm optimization) algorithm dramatically extended the network's lifetime. The technique needs to be sufficiently stable, and the clustering model must accurately capture undersea energy use characteristics. This manuscript presents a novel clustering model for UWSNs and a state-of-the-art clustering method based on the PSO algorithm to overcome the above-mentioned limitations.

A clustering technique is proposed based on the residual energy of sensor nodes and their vicinity which produces better clustering results than the LEACH method.

Routing protocols like LEACH, E-LEACH, and C-LEACH rely on the notions of moderate node mobility and gradual topological changes in the network. The analysis of these protocols is shown in Table 1 [2].

Table 1. Analysis of LEACH, E-LEACH, and C-LEACH Protocol

Protocol/Comparison Factor	LEACH	E-LEACH	C-LEACH
Clustering type	Distributed	Distributed	Centralized
Overhead	High	High	Low
Scalability	Good	Moderate	Low
Quality of service	High	High	High
Model of delivery	By Cluster head	By Cluster head	By Cluster head
Location information of node	No	No	Yes
Delay	Low	High	Low

Optimization Techniques for Underwater Wireless Sensor Networks

To find a solution to challenging or complex problems, optimization involves either maximization or minimization of the objective function. Since meta-heuristic algorithms are used to resolve optimization problems, optimization is also sometimes referred to as meta-heuristic optimization.

There are two distinct types of meta-heuristics algorithms: population-based and single-solution-based. Single-solution-based search is restricted to local results because it is exploitation-oriented. In contrast, population-based search is exploration-focused, confining the search results to the entire planet to find a good solution. Simulated annealing and tabu search are examples of techniques based on a single solution. Evolutionary algorithms and swarm intelligence are two forms of population-based approaches. Differential evolution and GAs are examples of evolutionary algorithms. Methods associated with swarm intelligence include PSO, ACO, ABC, cuckoo search, and firefly algorithm [11]. Analysis of some optimization techniques is shown in Table 2 [3].

Table 2. Critical Analysis of Optimization Techniques

Technique	Evolution	Methodology	Performance	Applications
ABC (Artificial Bee Colony) Optimization Algorithm.	Proposed by Karaboga in the year 2005.	This algorithm is based on the random behavior of natural ants. This algorithm aims to produce the optimal number of test cases in less time and using a smaller number of resources.	This algorithm deals with complicated problems efficiently. Few parameters are used in this as compared to other algorithms.	Traveling salesman problem, bio-informatics, scheduling applications, image processing, clustering etc.
PSO (Particle Swarm	Proposed by Kennedy	This algorithm is a global optimization algorithm that finds	This algorithm is based on	Min-max problems,

Technique	Evolution	Methodology	Performance	Applications
Optimization)	and Eberhart in 1995.	The best solution in D-dimensional space. In this technique, particles move in the problem spaces that follow the present optimal moving particle.	the cooperation of each particle. Fewer parameters are required for the calculation of optimized value in this algorithm.	classification of images, artificial neural networks, etc.
AC (Ant Colony) Optimization Technique	Proposed by Marco Dorigo in 1991.	This algorithm is inspired by the behavior of natural ants. Pheromone is used by ants in collaboration to resolve their problems. Pheromone is placed on the ground and ants go after a path where pheromone intensity is high.	This algorithm takes less computational time to find the optimal solution. By modifying the transition rule performance of this algorithm can be increased.	Job Shop Scheduling, Vehicle routing problems, sequential ordering, graph coloring problems, etc.
Genetic Algorithm	Introduced by John Holland in 1975.	In this algorithm, four operators are applied to find the optimal solution: a. Initialization b. Selection c. Crossover d. Mutation	The genetic algorithm technique is used to find out the approximate or exact solution of an optimization problem. In this generally global optimal solution is found.	Global optimization, Scheduling problems, Power system problems, Wireless ad-hoc networks etc.

LITERATURE REVIEW

The researchers looked into several study frameworks, models, and techniques to improve UWSN system performance. The research contributions of the researchers are presented for UWSN models in this section. This section talks about the research contributions along with method and model advancements.

Karim et al. [4] investigated that due to the special characteristics of the UWSN environment, data transfer in UWSN appears to be a more difficult task than in Terrestrial Wireless Sensor Networks. The authors suggested two network architectures based on multiple sinks: ANCRP and VH-ANCRP which were used to manage the local maximum nodes in order to achieve correct data transmission metrics. The network space was partitioned into tiny cubes to form clusters. Then, every cube receives an anchor node which serves as the CH. The source nodes were randomly distributed since each cluster head was linked to a string at the cube's center. In ANCRP, the source nodes were responsible for relaying the detected data to the designated CH. After the data packets were successfully transmitted to the surface sinks, the CH continued the transmission process by transferring the sensed data to the next-hop CH. CADC a method explained by Seyed et al. [5], consists of a number of sensors that were designated as CHs in order to gather data locally from their members. The AUV will then devise a nearly perfect route to follow in order to stop at each CH, gather data packets, as well as transfer them to an on-surface static sink. The CADC may be used in both connected and disconnected networks and is very extensible. A new metaheuristics-based clustering routing protocol MCR-UWSN was proposed by Neelakandan.

A Depth-Based Energy Balanced Hybrid (DB-EBH) routing protocol which uses the concept of an integrated clustering approach and the Energy Efficient Hybrid Clustering (EEHC) protocol for UWSNs was proposed by Ejaz, Mudassir [6]. Analysis of some techniques based on optimal clustering is shown in Table 3.

Table 3. Analysis of Techniques Based on Optimal Clustering in UWSN

Ref No.	Methodology Used	Description	Conclusion
[7]	Dynamic Hierarchical clustering data gathering algorithm	An intuitionistic fuzzy analytic hierarchy process and hierarchical fuzzy integration were employed to create a clustering topology model for balancing the energy consumption of the sensor network.	Improved network coverage and data-gathering capability.
[8]	Discrete PSO algorithm.	Effective clustering model implemented with discrete PSO algorithm. Clusters were formed using transmission power, residual energy, and cluster head loads.	Network lifetime and PDR were improved.

Ref No.	Methodology Used	Description	Conclusion
[9]	Node selection algorithm based on PSO.	The cluster head node was selected using the particle swarm optimization technique.	Since PSO was used as an optimization algorithm the lifespan of the network was enhanced.
[10]	Data fusion and genetic algorithms.	Data fusion was improved by using a drive approach which can lessen energy consumption.	The packet loss rate was reduced and no data redundancy was there.

OVERVIEW OF PARTICLE SWARM OPTIMIZATION TECHNIQUE

Particle Swarm Optimization (PSO) is one of the effective soft computing methods which may be used to tackle optimization problems. The PSO approach is excellent at escaping local optimum because it takes into account both local and global viewpoints simultaneously. In the PSO procedure, the swarm possesses the specified number of particles. These particles can be identified in the seeking space by the fact that the searching point has no mass or volume. Each particle moves through the search space at a specific speed that is dynamically changed by the population of that particle. Every particle traverses the searching space at a velocity that is dynamically determined by the particle's population. The swarms of n-particles are positioned in the space of the S dimension. Then, the position of particle i is expressed using a vector with an S dimension as:

$$Xi = \{xi1, xi2, xis\}$$

Velocity vector of particle $Vi = \{vi1, vi2, vis\}$

The best position of the particle is denoted as $Pi = \{pi1, pi2, pis\}$ where $i = 1, 2, ...z$. The value of the position of the particle is denoted by a fitness function. The best position value of the population of all particles is represented as:

$$Pg = \{pg1, pg2, pgs\}$$

Equations (1) and (2) are used to calculate both the velocity and position:

$$Vis\ (t+1) = w.\ vis(t) + c1.r1.\ (pis-xis) + c2.r2(pgs-xis) \quad (1)$$

$$Xis\ (t+1) = xis(t) + vis(t+1) \quad (2)$$

Where $1 \le i \le n$; $1 \le s \le S$; w represents the inertia weight, which indicates the retaining rate for the particles' velocity; t represents the length of each iteration; r1 and r2 are random numbers among 0 and 1 that are used to maintain the diversity of the population. c1 and c2 are acceleration coefficients that represent the contribution of the information factor and the common factor, respectively.

The total number of cluster heads, denoted by Tj, is calculated for each initial cluster as part of solving the clustering problems using PSO. When S particles are initialized then each particle is considered a vector with two times 2XTj dimensions. Zi= {zi11; zi12; zi21; zi22;…ziTj1; ziTj2} where zik1 and zik2 are the coordinate of cluster head k. The dimension value in the velocity of the particle is limited by vmax [11].

PSO Design for UWSN

PSO is an innovative localization approach for UWSNs which does not rely on signal nodes. The PSO localization process makes up the entirety of the localization process.

Since the objective function in Equation (3) is a non-linear function of the location variable X, the minimization problem associated with it does not have any analytic solutions. Traditional optimization techniques, including gradient descent, have a high propensity to get stuck in a local optimum and a slow rate of convergence. To find a solution to this problem, the PSO method is used.

$$\min \sum_{Z_{i,j} \in Z} Z_{i,j}^{-2} (Z_{i,j} - d_{i,j} - \mu_{\alpha} d_{i,j})^2 + \sum_{i=1} \delta I (X_i - \hat{X}_i)^2 \quad (3)$$

The particle that best fits the objective function is identified after moving a population of particles repeatedly to the optimal local and global solutions using the search space as a guide. By simultaneously integrating local and global viewpoints, the PSO approach can successfully avoid the local optimum.

In addition to the location variable X, the optimization variables in Equation (4) additionally include. Consequently, there are a total of 2M + 1 variables, that can be signified as {{xi}Mi=1, {yi}Mi=1, μα}. Suppose that NP particles have been initialized, or that {Pk}NPk=1. Each particle represents a unique instance of the set variable. To decrease the search space, the position of the particle is initialized as follows:

$$P_k{}^1 = \begin{Bmatrix} X^1{}_A\text{-}r1+rand*2r_1 \\ Y^1{}_A\text{-}r1+rand*2r_1 \\ X^M{}_A\text{-}r_M+rand*2r_M \\ Y^M{}_A\text{-}r_M+rand*2r_M \\ \mu_\alpha{}^L+rand*(\mu_\alpha{}^u-\mu_\alpha{}^L) \end{Bmatrix} \quad (4)$$

Where rand is a random number among [0, 1]. μLα and μUα stand for the lower and upper bounds of velocity respectively. After initiation particles move with a specific velocity to new locations in the search space. The particles can determine the pBest best local position by evaluating the goal function's value. The particles will then connect to determine the optimal global position, gBest [11].

Reason for Using PSO Over Other Optimization Techniques

PSO is considered one of the best optimization algorithms due to its flexibility and ability to produce optimum performance in underwater wireless sensor networks.

In this algorithm position and velocities of the particles in search space are updated regularly using the iteration method.

This algorithm is simple in nature and very effective in complex environments i.e., in underwater environments.

PSO algorithm can be hybridized with other algorithms to further improve its performance.

PROPOSED METHODOLOGY AND ALGORITHM

Many of the problems in the UWSN like the deployment of nodes, localization, and energy-aware clustering are considered as a typical issue of optimization. The proposed optimization technique is built on swarm intelligence and crusade. The PSO algorithm is used to solve problems by utilizing social interaction. This algorithm takes advantage of the swarm of particles which roam the search space in quest of the optimal answer. Each particle behaves as a point in N-dimensional space which modifies its "flying" in response to both its own experience and that of other particles. The routing protocols are divided into groups based on many different parameters. The LEACH protocol is considered for the bulk of these applications.

PSO begins with a collection of random particles and then iteratively modifies generations in search of the optimal solution. After two iterations, each particle is updated using the "best" values. The first one provides the best (fitness) results and this value is known as p-best. The particle swarm optimizer also maintains a record of the best value reached by any particle in the population to date. This best price is a global best and is referred to as g-best. NS-2.35 simulator is employed to carry out the working of the proposed protocol.

In the proposed technique, LEACH protocol is utilized with the PSO technique. In the LEACH protocol, there is an uneven distribution of cluster heads, so more energy consumption is there. In the proposed protocol, the load limit value is taken to ensure balanced clustering. M no of swarm particles are distributed over the network. Then communication is started for a defined number of rounds and a threshold value is set for each sensor node. The node having a higher energy value than a threshold value is elected as the cluster head node. The coverage area of the respective cluster is defined and the degree of nodes is attached for each node. The nodes having degrees 1 and 2 are attached to the nearest cluster. Due to load factor, degree of nodes, and residual energy concept, balanced clustering is performed in this protocol. After cluster formation communication is performed between sensor nodes and base station node. After 100 seconds of simulation time, residual energy is again calculated and the same procedure is followed to choose the next cluster head node. The node having zero value of residual energy is considered as a dead node and others are denoted as alive nodes. In this way, communication is performed and energy is checked for each round. Based on various factors, it is concluded that the proposed protocol is better than other previous protocols in terms of energy conservation.

Algorithm of the Proposed Protocol Using PSO

Define N sensor nodes with floating mobility between 0 to 5 mt/min

Define the base station as the receiver node

Define the Load Limit for ensuring the load-balanced clustering

Generate M swarm particles and distribute them over the network. Characterize each swarm with a characterized region of radius R

For r=1 to Communication rounds

{

For p=1 to M

{

nodes= p. get Nodes(R)

For i=1 to nodes. count

{

Compute Threshold T(i) using LEACH protocol threshold selection equation and generate random value x(i)

$$T(n)= \begin{cases} \dfrac{P_t}{1-P_t(r.\text{mod}1/P_t)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where: T(n)= calculated threshold value

P_t= cluster head percentage

R= number of communication round

G= number of nodes which have not been selected as head nodes in previous rounds

If x(i) <= T(i) //Random Parameter

{

if (Nodes(i). E>max)

{

max=Nodes(i). E

c=i

}

}

}

Set nodes(c) as CH

nodes=CH. get Nodes (Coverage)

degree 1 =get One Degree Node (nodes)

degree N =get N Degree Node (nodes)

if nodes>Load Limit

{

If degree1>m*limit/100 //Minimum overlapping

{

Broadcast the CH info to its m cover nodes and consume the transmitting energy.

Count=0;

For j=1 to nodes

```
{
If (node(i). degree=1)
{
nodes(j).CH=i
count=count+1;
}
}
For j=1 to nodes
{
 if (node(i). degree>1 and count1<Load Limit)      //Check for global best
{
node(j).CH=i
count=count+1;
   }
   }
For j=1 to Load Limit
   {
If (Coverage(node(j), node(i)) =True)
{
Perform Communication (node(j), node(i))
node(j). Energy=node(j). Energy-Tx*DSize
if (node(j). Energy<=0)
{
Dead=Dead+1
)
Else
{
Alive=Alive+1
}}}}}}
```

Explanation of the Proposed Algorithm

This algorithm provides the PSO integrated algorithm to optimize the clustering and communication in underwater sensor networks. This optimization algorithm is capable of providing the solution against various challenges including floating nodes, limited communication, and coverage capabilities of sensor nodes. A scalable network with N sensor nodes is defined with floating nodes. A fixed-position base station is defined as the controller and receiver node. The load limit is defined to control the load and capacity on the coordinator node. As the algorithm initiated, M swarm particles are distributed over the network at random positions. Each of the swarm elements is defined as the observer that can analyze the node within the R radius. The node, communication, and network information can be collected by these swarm particles. The communication is performed for a fixed number of rounds and with each round swarm particles are observing the sensor nodes under different parameters. These parameters are the connectivity, energy, and load. Each swarm particle identifies the nodes within the range. Now each covered node is processed and the probability value for setting the node as cluster head. The equation is defined in the algorithm for selecting a node as a cluster head. A threshold value is defined to validate the eligibility of a node as a cluster head. If the node validates its limit, then the second parameter is analyzed by the swarm particle e.g. degree of coverage nodes. Each of the sensor nodes identifies the number of nodes in its coverage with respective degrees. A separate analysis is performed on degree-1 and degree-N nodes. The number of nodes in the coverage is analyzed respectively to the load threshold to validate the load limit against the underload situation. If the node is eligible, then identify the number number of nodes with degree-1. If a node significant balance of degree-1 and degree-N nodes exist in the coverage, then node quality under the 2nd and 3rd parameters. Energy is the 4th parameter that is used as and pre-qualifier to set a node as a cluster head. If all these parameters are validated for a specific node, then it can be set as cluster head otherwise node is a normal communication node. Now the communication is performed between the node and cluster head and with each communication significant amount of energy is lost for each node. This process is repeated till any of the nodes has some energy or the number of communication rounds is not completed. The algorithm is simulated with some real-time parameters and the simulation results are provided in the next section.

Flow Chart of Proposed Technique

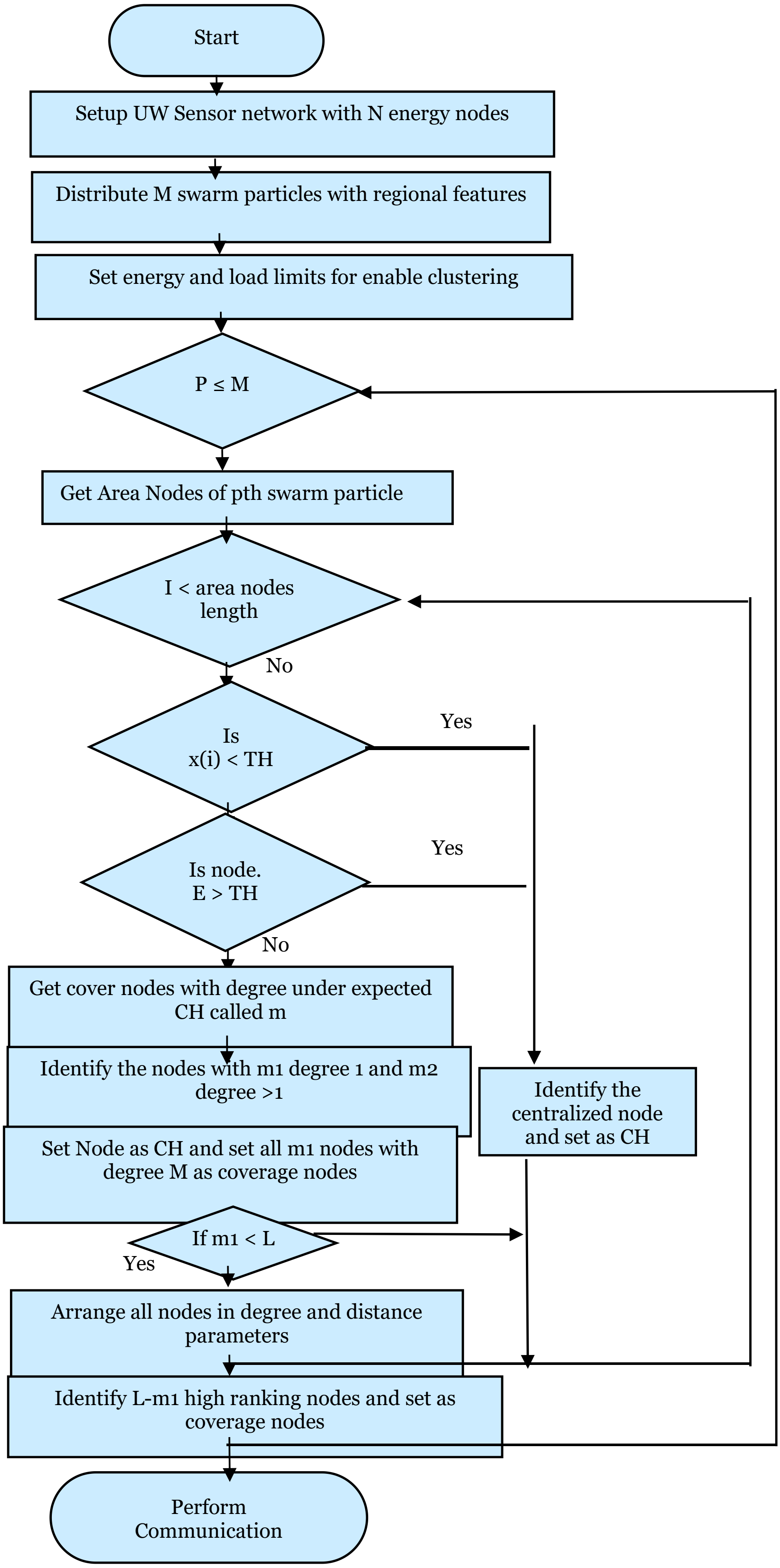

Figure 1. Flow Chart of LOAD BALANCED LEACH Protocol

As the flow chart starts, a scalable underwater network with N sensor nodes is defined in which nodes are floating. In the next step, M swarm particles with regional features are distributed over the network at random positions. In the next phase, energy and load limits are finalized to enable clustering. Each swarm particle identifies the nodes within the range. Now each covered node is processed and the probability value for setting the node as cluster head. Now the area nodes of pth swarm particles are set up. After that, a threshold value is defined to validate the eligibility of a node as a cluster head. If the node authenticates its limit then the degree of coverage nodes is analyzed by the swarm particles. Each of the sensor nodes identifies the number of nodes in its coverage with respective degrees. After that, the nodes are identified with degree values. In the next step, a cluster is set up having a head node and all the degree 1 nodes as its coverage nodes. All nodes are arranged in distance and degree parameters. Energy is the 4th parameter that is used as and pre-qualifier to set a node as a cluster head. In the next step, communication is performed.

PERFORMANCE EVALUATION

To assess and validate the analytical model, a simulation-based performance evaluation of the LOAD BALANCED LEACH procedures is presented after the analytical results. Various aspects like consumption of energy, packets transmitted, number of alive nodes during transmission, bytes transmitted, no. of dead nodes, and bit-rate transmission are analyzed. These factors provide a good execution metric to estimate the performance of UWSN protocols. The main focus of the proposed technique is to conserve energy. Energy is consumed in data transmission and reception. The performance of the proposed Load-Balanced LEACH protocol based on the PSO Algorithm is compared with LEACH, C-LEACH, and E-LEACH in terms of throughput, PDR, as well as energy efficiency.

Simulation Setup

Simulation studies utilizing a PSO algorithm are carried out so that a validation of the analytical model and a comparison of the performance of the LOAD BALANCED LEACH protocol with that of LEACH, E-LEACH, and C-LEACH protocols can be made. Simulation is carried out using the NS 2.35 simulator. NS 2 is an event-driven simulation device for studying the performance of sensor networks. NS 2 provides support for both wired and wireless sensor networks. The underwater wireless sensor network is a multi-hop network containing both alive and dead nodes, and every node in the network has a predetermined purpose and a set data rate associated with it. There are a total of 100 nodes in this network, with nodes 1 and 10 serving as cluster chiefs. There are 100 nodes in this network.

The simulation's settings are detailed in Table 4, which can be seen here. Calculations are done to determine the total remaining energy in a node, the amount of energy lost while the node was in an idle state, and the energy used for transmission and reception.

Table 4. Simulation Parameters

Parameters	Values
Network zone	1000x1000
No. of nodes	100
Simulation time	100 sec
Protocols	LEACH, E-LEACH, C-LEACH, PSO LB LEACH
Initial energy	1J
MAC protocol	802.15.4
Mobility	0 to 5 mt/min
Energy threshold	2nJ
Transmission energy	5nJ
Receiving energy	5nJ

Simulation Results

Remaining Energy and Nodes Loss Rate Analysis

Energy efficiency is a fundamental factor for measuring performance when it comes to underwater wireless sensor network protocols. Energy consumption by the sensor nodes is the yardstick by which energy efficiency is evaluated. The purpose of the simulation is to investigate the impact that the data rate has. The graph is plotted between the remaining energy in joule and simulation time in seconds as shown in Figure 2. The initial energy for each node is taken approximately. equal to 1J. Energy is consumed during data transmission and degraded after every second. The energy level in the LEACH protocol degrades after 44 rounds. The energy of E-LEACH, C-

LEACH, and LB-LEACH based on PSO is 16.5044 j, 68.8387j, and 73.9919 respectively after 100 rounds. So, it is concluded that the PSO-based LBLEACH protocol is better than the other three protocols.

The following graph as shown in Figure 3 represents the number of nodes that are lost during the transmission after 100 sec of simulation time. The more the number of nodes lost less is the efficiency of the protocol. In Figure 3, it is clearly shown that the proposed protocol which is based on PSO methodology has a smaller number of lost nodes after simulation so it has the highest efficiency than other protocols.

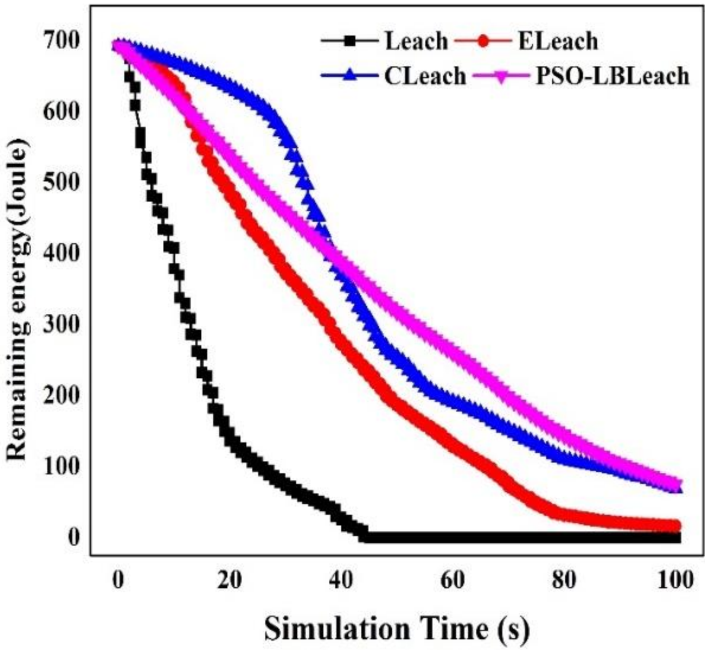

Figure 2. Remaining Energy VS. Simulation Time

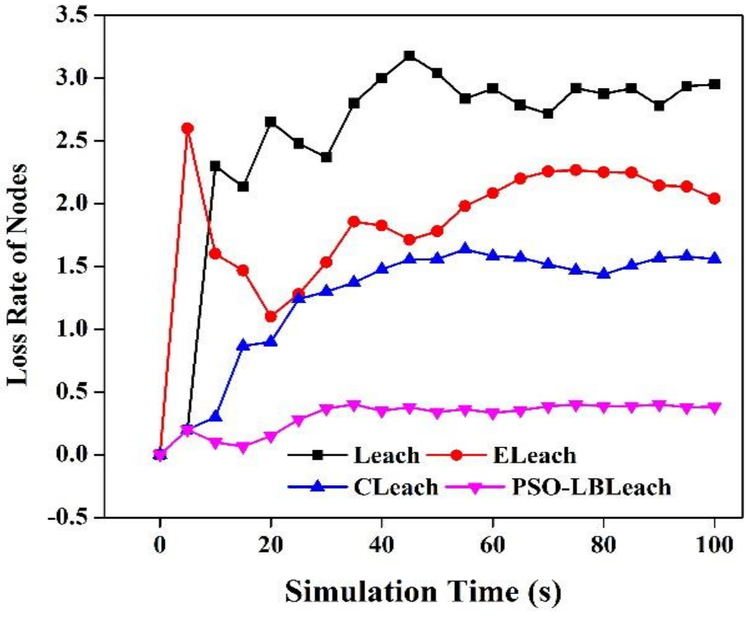

Figure 3. Number of Nodes Lost VS. Simulation Time

Number of Packets Transmitted and Packets Lost Analysis

Figure 4 below displays the number of packets transmitted in 100 seconds. The more the number of transmitted packets, more will be the efficiency. The graph shown below in Figure 5 is plotted between the number of packets transmitted and the time taken in the simulation. The number of packets transmitted to the base station over a given period is much more in LB LEACH than in LEACH, E-LEACH, and C-LEACH. The network's performance is dependent on both the amount of data received by the cluster heads and the amount of data delivered to the BS. This improves PDR, which in turn leads to an increase in the network's overall efficiency. The capacity of PSO stands in contrast to the number of packets that are lost as shown in Figure 5. It is because of the limited number of packets that can be kept, which causes the packet to be lost because it exceeds the capacity.

The packet delivery ratio is impacted when there is a loss of packets. The more the value of packet loss, the less the PDR value. Packet Loss in LB-LEACH in UWSN has a lower value than LEACH, E-LEACH, and C-LEACH protocols.

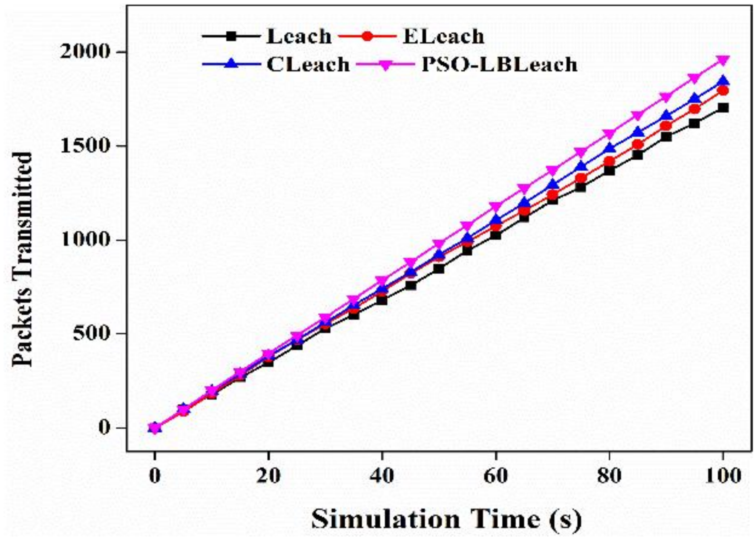

Figure 4. Packets Transmitted VS. Simulation Time

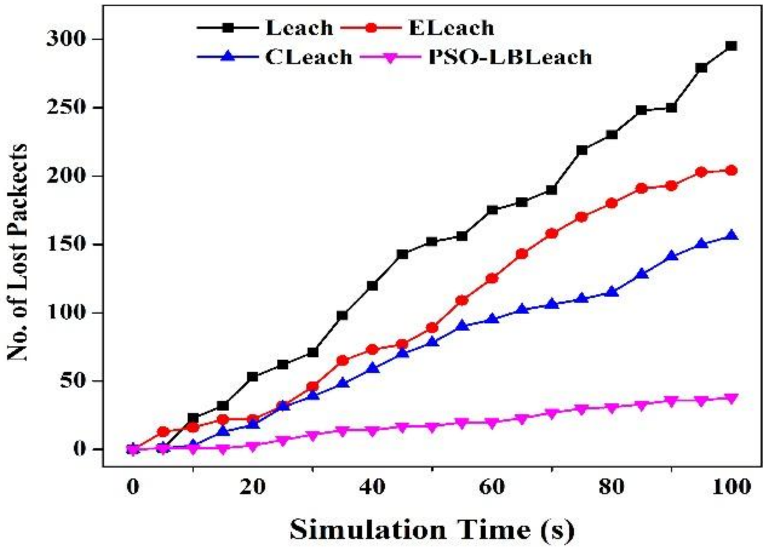

Figure 5. Packet Lost VS. Simulation Time

Dead and Alive Node Analysis

Figure 6 below presents the number of dead nodes in each round in LEACH, E-LEACH, C-LEACH, and LB LEACH. It is shown that no of dead nodes in the proposed protocol is lower than in the other three protocols. Nodes that have less energy left over are unable to become CH as a result of recently introduced energy criteria for CH selection. As a result, the likelihood of these nodes passing away is significantly reduced. Therefore, improved versions of the LEACH protocol i.e., LB LEACH lengthen the lifetime of the network by allowing a greater no. of nodes to survive until the end of the simulation. Figure 7 below represents the number of alive nodes after 100 sec of simulation time of four protocols and it is concluded that the proposed protocol i.e., LB LEACH is better than the other three existing protocols because of the presence of a greater number of alive nodes.

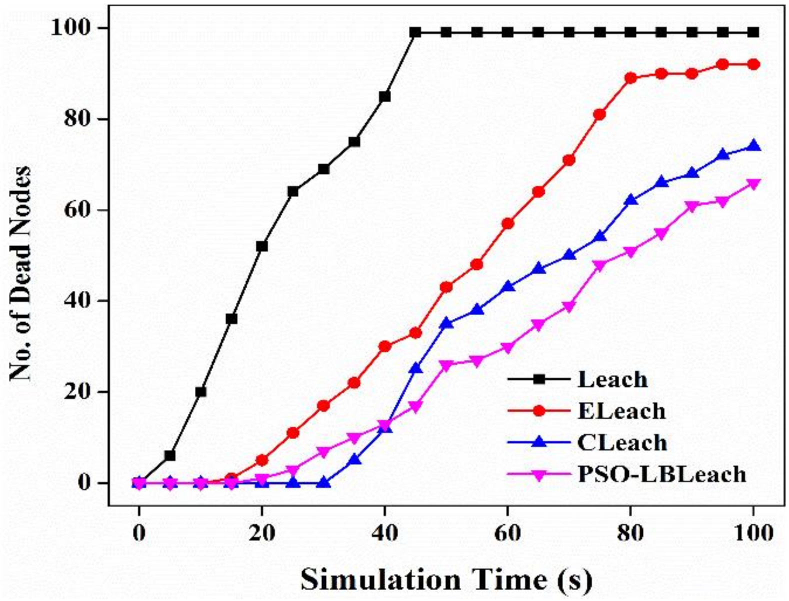

Figure 6. Number of Dead Nodes VS. Simulation Time

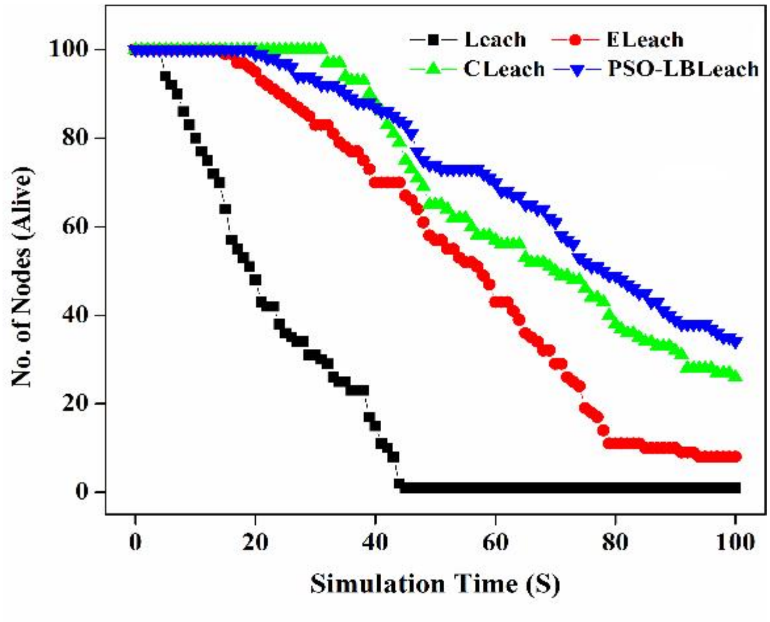

Figure 7. Number of Alive Nodes VS. Simulation Time

Bit Rate and Bytes Transmission Analysis

Figure 8 represents the bit rate analysis of original Leach, E-LEACH, C-LEACH, and LB LEACH protocols. The proposed protocol has the highest bit rate than any other three protocols. More the number of bits transferred more is the efficiency of the protocol. Figure 8 is plotted between the bit rate of packets transmitted versus simulation time. The graph is plotted between a number of data bytes transmitted to the base station by sensor nodes versus simulation time and it is concluded that the byte rate of the proposed protocol is higher than other existing protocols as shown below in Figure 9.

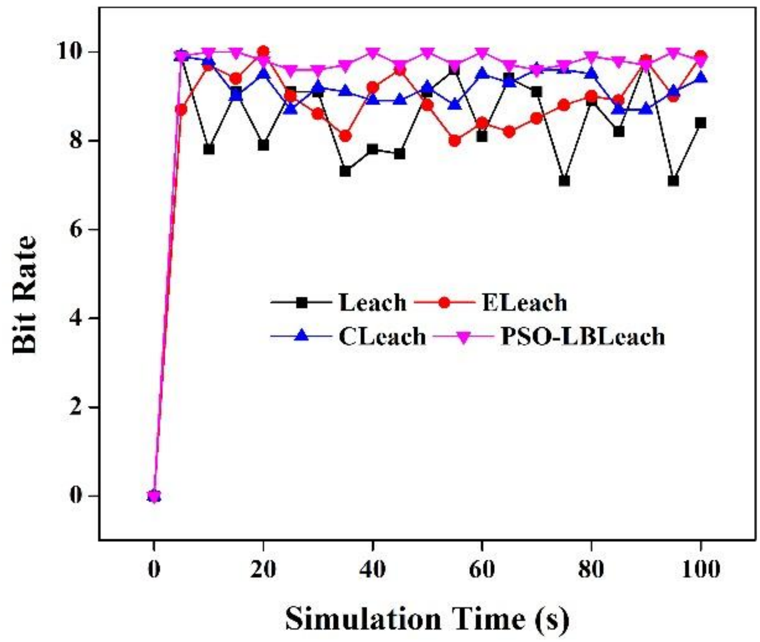

Figure 8. Bit Rate Analysis VS. Simulation Time

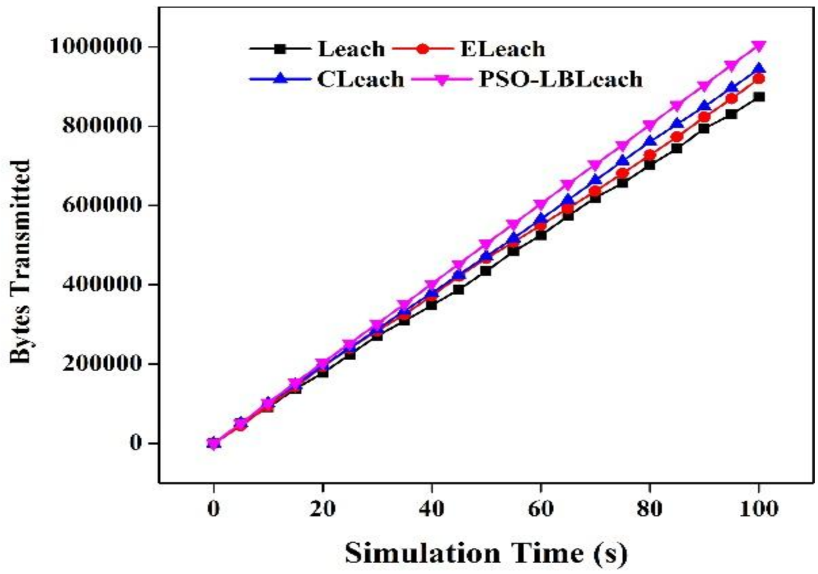

Figure 9. Number of Bytes Transmitted VS. Simulation Time

CONCLUSION

The main issue in underwater wireless sensor networks is high energy consumption by sensor nodes. The data transmission phase consumes more energy than other phases as this phase is hampered by several communication issues, including packet collision, overhearing, and interference. In UWSN, the density of sensors and the speed at which they communicate with one another have a major impact on the network's lifespan. A new protocol based on PSO optimization is suggested to reduce energy consumption in underwater wireless sensor networks. In this paper, Load Balanced LEACH protocol is proposed, which uses the concept of particle swarm optimization. This protocol is based on the LEACH protocol, which is a hierarchical clustering routing protocol. Some parameters are added in the proposed protocol, like load factor and distance parameter. The proposed protocol is then comparatively analyzed through simulation on NS 2.35 simulator with existing protocols, LEACH, E-LEACH, and C-LEACH, based on various factors like residual energy, packet delivery ratio, number of alive and dead nodes, bytes of packets transmission, loss rate, bit rate of packets, number of nodes lost during transmission. The result of the proposed protocol is more energy efficient and henceforth, it will lengthen the network lifetime. This paper only focuses on reducing energy consumption but it fails to provide the confidentiality and integrity of data. This work will be extended with the security concepts which will analyse the flow of data among sensor nodes. Hence in future, the proposed protocol is integrated with security mechanisms to protect the network from security attacks.

ETHICAL DECLARATION

Conflict of interest: No declaration required. **Financing:** No reporting required. **Peer review:** Double anonymous peer review.

REFERENCES

[1] M. Jouhari, K. Ibrahimi, H. Tembine, and J. Ben-Othman, "Underwater wireless sensor networks: A survey on enabling technologies, localization protocols, and internet of underwater things," I*EEE Access*, vol. 7, pp. 96879-96899, 2019.

[2] S. K. Singh, P. Kumar, and J. P. Singh, "A survey on successors of LEACH protocol," *IEEE Access*, vol. 5, pp. 4298-4328, 2017.

[3] M. Mamta, N. Goyal, and M. Nain, "Optimization techniques analysis in underwater wireless sensor network," *ECS Transactions*, vol. 107, no. 1, p. 5403, 2022.

[4] S. Karim, F. K. Shaikh, K. Aurangzeb, B. S. Chowdhry, and M. Alhussein, "Anchor nodes assisted cluster-based routing protocol for reliable data transfer in underwater wireless sensor networks," *IEEE Access*, vol. 9, pp. 36730-36747, 2021.

[5] S. M. Ghoreyshi, A. Shahrabi, and T. Boutaleb, "An efficient AUV-aided data collection in underwater sensor networks," in *2018 IEEE 32nd International Conference on Advanced Information Networking and Applications (AINA)*, May 2018, pp. 281-288.

[6] M. Ejaz, N. Javaid, H. Maqsood, U. Shakeel, Z. A. Khan, and U. Qasim, "An energy efficient hybrid clustering routing protocol for underwater WSNs," in *2016 30th International Conference on Advanced Information Networking and Applications Workshops (WAINA)*, Mar. 2016, pp. 526-532.

[7] X. Song, W. Sun, and Q. Zhang, "A dynamic hierarchical clustering data gathering algorithm based on multiple criteria decision making for 3D underwater sensor networks," *Complexity*, pp. 1-14, 2020.

[8] P. Li, S. Wang, H. Zhang, and E. Zhang, "Improved particle swarm optimization algorithm of clustering in underwater acoustic sensor networks," in *OCEANS 2017-Aberdeen*, Jun. 2017, pp. 1-7.

[9] E. Cheng, L. Wu, F. Yuan, C. Gao, and J. Yi, "Node selection algorithm for underwater acoustic sensor network based on particle swarm optimization," *IEEE Access*, vol. 7, pp. 164429-164443, 2019.

[10] X. Xiao, H. Huang, and W. Wang, "Underwater wireless sensor networks: An energy-efficient clustering routing protocol based on data fusion and genetic algorithms," *Applied Sciences*, vol. 11, no. 1, p. 312, 2020.

[11] M. Jain, V. Saihjpal, N. Singh, and S. B. Singh, "An overview of variants and advancements of PSO algorithm," *Applied Sciences*, vol. 12, no. 17, p. 8392, 2022.