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Clustering Base Energy Efficient Mechanism for an Underwater Wireless Sensor Network

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Abstract
Underwater sensor networks are significantly different from terrestrial networks due to certain characteristics of low bandwidth, high proliferation delay, absorption, attenuation and limited energy. These unique features cause challenges in the development of protocols for underwater sensor networks (UWSNs) by researchers. In any case, energy conservation is one of the characteristics that ought to be considered. In this paper, considering the underwater (UW) constraint, we propose an energy conservation methodology that benefits from the use of the LEACH calculation method for UWSNs. The simulation results of our proposed hierarchical clustering strategy for UW networks are compared with the hierarchical clustering strategy of LEACH of terrestrial networks and show that the proposed methodology for UWSNs matches that of LEACH for terrestrial WSNs. Similar to the LEACH protocol, the proposed methodology also reduces the total energy consumption and prolongs the life of the UWSN. In a certain round, the number of nodes that are alive and the life of the network remain the same.

Keywords Underwater sensor network · LEACH · Hierarchical clustering strategy

1 Introduction

To connect marine studies around the world, researchers work on underwater sensor networks. Underwater sensor networks are deployed for many applications, such as environmental monitoring, disaster prevention and underwater exploration. An underwater sensor network is composed of special sensor nodes with acoustic modems and is distributed in water [1]. Each spread node senses different environmental information, such as

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temperature, pressure, and chemical and biochemical elements, and sends this information to a surface station. In UWSNs, communication is established through acoustic waves instead of radio waves because this approach allows for very good propagation through water and requires less power consumption; however, this approach is much slower than the use of radio waves.

Compared to the radio channel bandwidth, the bandwidth of the UW channel is very limited and dependent on both range and frequency [2, 3]. The limited bandwidth of UWSNs, which is caused by high absorption factors and attenuation and propagation, has generated interest among researchers. Another important factor is sensor node failure due to environmental conditions. Energy conservation is another important constraint of UWSNs that greatly affects the lifetime of a network. Due to the harsh environment of the UWSN, it is impossible to replace or recharge network nodes, which causes network depletion However, routing techniques can resolve the issue of network energy conservation by considering its most effective parameters, such as limited bandwidth, long propagation delays and attenuation.

The distinctive features of UWSNs have increased researchers' interest in studying their architectures and networking protocols. Based on this interest, we developed an energy efficient algorithm that is a modified form of LEACH for UWSNs. The LEACH algorithm [4] is the most well-known energy efficient clustering algorithm used in terrestrial wireless sensor networks. We investigated the environmental changes of underwater WSNs compared to terrestrial WSNs and modified the conventional LEACH algorithm considering underwater physics parameters. To implement our suggested scheme, we use MATLAB simulator to perform various experiments to observe performance parameters such as the network lifetime, number of nodes that are alive or dead, and energy conservation of the network.

This paper is organized as follows. A brief introduction to UWSNs and their constraints and limits, particularly in acoustic communications, is presented in Sect. 1. Section 2 is dedicated to related works that address architecture issues and routing protocol issues in UWSNs. In Sect. 3, we present the system model, and in Sect. 4, we present the proposed approach. In Sect. 5, we present the experimental results and analysis. Section 6 includes the conclusion and future work.

2 Literature Review

Underwater sensor networks have become an innovative field of interest for researchers. Various researchers [1–3, 6–10] have identified their unique qualities and addressed their configuration issues for efficient network communication. Compared with ground-based networks, UWSNs offer the key properties of acoustic wireless communication, variable and high propagation delays, limited available bandwidth, high bit error rate and limited battery power. Several researchers have devoted many efforts to design a new energy efficient routing protocol for UWSNs by managing the most effective parameters [11–25].

Due to the unique challenges of underwater environments, the communication protocols proposed for terrestrial networks cannot be directly applied to UWSNs. Many protocols have been proposed for UWSNs taking into account the unique features of underwater networks, including media access control and network and transport protocols. Pompili et al. [12] worked on acoustic sensor network mixed-media cross-layer convention and proposed an efficient plan for sharing the data transfer capacity of dispersed cross-layer networks.

Harsh and unpredictable underwater environments make routing more challenging than in cases of terrestrial wireless sensor networks. Most of the existing schemes deployed mobile sensors or a mobile sink (MS) to maximize data gathering. Yahya et al. [13] and Javaid et al. [14] worked on sink mobility and employed an AUV for gateway data gathering. AEDG employed an AUV for data gathering from gateways and used a shortest path tree (SPT) algorithm while connecting sensor nodes with the gateways. To minimize the network energy consumption, the number of nodes associated with the gateway was restricted, and the AUV allowed for dynamic data collection. Jing et al. [15] researched the fading channel demultiplexing asymmetric communication protocol (AMDC), employed an AUV for data collection from gateways and worked on the shortest path tree (SPT) algorithm to identify the best path for routing. Due to the difficulty of underwater sensor charging or replacement, some researchers have worked on energy harvesting techniques. Khan et al. [16] investigated energy allocation in underwater acoustic nodes powered by energy harvesting and proposed an energy management and power allocation mechanism to maximize the expected total amount of data delivered over finite time slots.

The routing protocol strategy for UWSNs faces the challenge of route selection. Zhou et al. [17] worked on free Q-learning base localization and the any path finding protocol, with the Q-value based on residual energy and depth information of sensor nodes. This scheme also introduced a new holding time mechanism for packet forwarding according to forwarding candidate nodes. Khalid et al. [18] proposed a higher energy efficiency and delivery ratio and a multilayer routing protocol. This approach is location-free and maintains a priority table for routing. This approach works well in terms of the packet delivery ratio, end-to-end delay and total energy consumption.

Rani et al. [19] suggested an energy-efficient chain-based routing protocol for UWSNs. His strategy considered the energy of cluster heads (CHs), relay nodes (RNs) and cluster coordinators (CCOs) for the transmission of data and suggested that for the conservation of the energy role of each CH, RNs and CCOs will change after a specific time. On the other hand, Tan et al. [20] proposed a cooperative transmission scheme, and multihop scheme relay nodes were employed as virtual antennas to achieve diversity gains. The destination and potential relay nodes were selected on the basis of distance cost and local measurement of channel conditions. The proposed scheme performed well in terms of average energy consumption, packet delivery ratio, and end-to-end delay. Sender-receiver role-based energy-aware scheduling for the Internet of Underwater Things (EAST) [21] was proposed by Xu et al. The work of proposed system offers three novel features: a probability-based contending model for achieving high energy efficiency, a role-based spatial and temporal reuse approach, and a sender-initiated behavior model using prospective theory to address the problem of packet loss with uncertainty.

Nadeem et al. [22] presented two efficient and balanced energy consumption techniques (EBETs) and an enhanced EBET (EEBET). The EBET preserves energy by avoiding direct transmission over a long distance. Initially, the energy of sensor nodes is divided into energy levels. Data transmission on the basis of relay nodes is performed through higher energy nodes and avoids long-distance direct transmission. The EEBET reduces the number of hops between the source and sink with the incorporation of a depth threshold while eradicating backward data transmission. The EBET strategy balanced energy consumption within successive sectors, while the EEBET balanced the energy consumption of the entire network. These strategies are not as appropriate for real-world scenarios they were validated with a simulator and consider only a few parameters of underwater transmission.

In the network clustering routing strategy, the cluster head collects the data from its cluster and sends it to the sink instead of each node connected to the sink and extends the life of networks. Wan et al. [23] proposed an energy-efficient multilevel adaptive clustering routing algorithm for UWSNs. This algorithm worked on a multilevel hierarchical structure, and clusters were formed on the basis of the residual energy of the cluster head and the distance between the CH and sink and avoided the death of the CH away from the sink due to an excessive competition radius leading to excessive energy usage. Zhu et al. [24] also worked on 3D layer architecture and suggested a localization-free routing protocol based on layers and unequal clusters in UWSNs. This scheme was an attempt to avoid the "hot spot" problem with an unequal clustering method based on layers and a new calculation method of unequal cluster size. Anuradha et al. [25] also proposed an energy efficient reconfigurable cluster base routing strategy and controlling node failure to optimize network performance.

Clustering is one of the more commonly anticipated routing techniques since it can support increasing the system's scalability while concurrently decreasing its energy consumption. One of the most well-known clustering-based protocols is the LEACH protocol. LEACH is a self-organizing, adaptive clustering and scheduling protocol [26, 27]. Numerous works in the literature have proposed approaches to improve the LEACH protocol to be modified for UWSNs, as presented in Table 1. Their main objective is to adjust a LEACH protocol for UWSNs through progress in several parameters, such as cluster constancy, delay adeptness, load balancing, data reliability, failure retrieval and energy efficiency. However, the energy efficiency under consideration of UW physics parameters is not sufficiently discussed and investigated in the literature. Therefore, this paper proposes an energy aware mechanism concerning major UW physics parameters based on LEACH that is adapted to UWSNs and aims to minimize their energy consumption.

3 System Model (A Shallow Water Network)

Since an underwater sensor system is a 3D system, 3D organized topology is required [6, 7]. A submerged sensor system model is represented by a 3D square in Fig. 1, and it consists of a number of nodes operating in a shallow water environment at a depth of 75 m. All the sensor nodes are tied to the base of the sea grapples. Based on the proposed methodology, the zone is separated into clusters, and each head of the cluster gathers its group information and forwards the gathered information to the sink in its transmission availabilities.

UW sinks are equipped with vertical and flat acoustic receivers. The flat receiver is utilized to connect with the sensor centers, and the vertical connection is utilized to transfer gathered information to a surface station. The surface station is equipped with an acoustic receiver for managing numerous parallel interchanges with the sent UW sinks in the system and is furthermore prepared with long-range RF or satellite transmitters to communicate with a coastal or ship-based sink. A model plan of the proposed framework is shown in Fig. 1.

3.1 Underwater Sensor Model

The system model has the following associated properties:

1. Each of the sensors in the system has a unique ID and an equal energy
2. All nodes have constrained energy
3. The nodes are static and secured to a base of sea stays.

Table 1 Comparisons of LEACH based protocol with proposed methodology

Protocol scheme	Contribution	Deficiencies	Advantages achieved
HMR-LEACH (Hierarchical multipath routing-LEACH) [28]	Works in two phases: 1. multipath establishment based on color-coded information; 2. the selection of the path To transmit data from the transmitter to the sink, it selects a path based on the minimum count of the number of hops and the larger weight of the path from the cluster to a sink	Multiple mechanisms are missing: cluster head selection, color-coded information, hop count mechanism; Due to improper hop count mechanism, the definition of energy efficiency is baseless; Unnecessary route request-response messages lead to additional overhead; Multiple factors of UWSNs are not considered for data routing	Multi hop architecture Improves the data delivery ratio; minimizes the energy consumption
L-LEACH local update clustering algorithm [29]	Works in two phases: 1. determines an optimum number of cluster heads 2. applies a local management approach for cluster head selection	Unique parameter of UW communication has not been considered; Missing local management scheme; Not applicable for UW communication Mechanism is the same as that of F-LEACH	Reducing the cluster head election phase and conservation of the energy of the network Reduces end to end delay
Adapting LEACH algorithm for underwater wireless sensor networks [30]	Integration into the LEACH algorithm, the energy model used in submarine networks for data transmission	The energy model considers only losses due to absorption factor; Missing major factors of UW communication; Missing cluster head selection and cluster formation mechanism	Energy efficiency; data Delivery performance; extension of network lifetime
UMOD_LEACH energy aware approach for UWNs scheduling [31]	Adaptive LEACH with localization used to minimize energy consumption Single hop and 2D model. The aim of the protocol is to improve the advertisement phase of clustering	Missing multiple factors of UW communication; missing propagation delays. Only the propagation speed of sound is considered The localization is not perfect because of the mobility of sensor nodes and the harsh environment	Energy efficient; improves the advertisement phase of clustering and extends network life

Table 1 (continued)

Protocol scheme	Contribution	Deficiencies	Advantages achieved
Modified LEACH for UWSNs (proposed)	Modified conventional LEACH through UW propagation model and unique parameters (propagation speed of sound, transmission delays and throughput)	Single hop protocol 2D architecture Localization free	Energy model based on delays due to absorption and spreading and propagation speed of sound; Localization free due to mobility of sensor nodes, hash environment localization is not perfect, and localization free protocols are highly demanded by researchers; Improves network life and minimizes network energy consumption Improves data delivery ratio and network communication

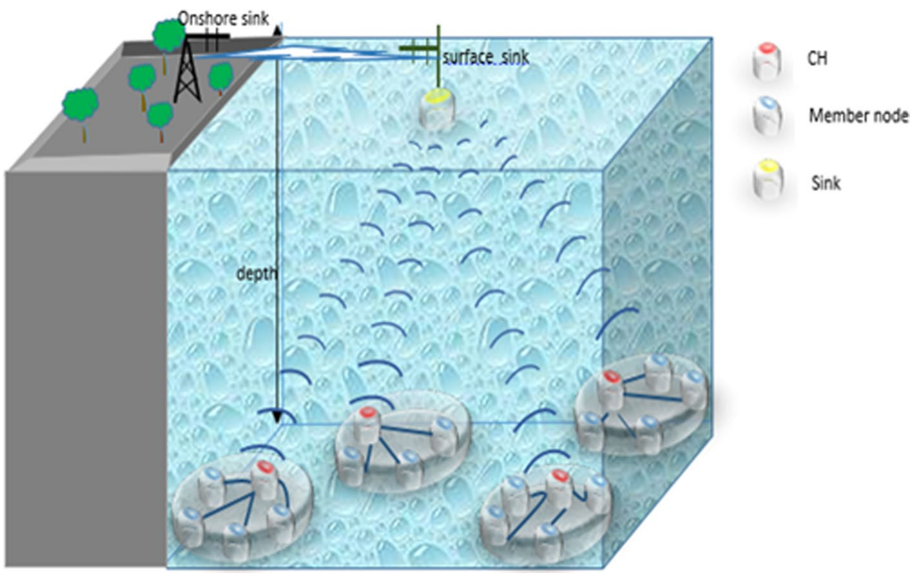


Fig. 1 Model diagram of proposed system

The distance between nodes is computed as Eq. (1):

$$d(i,j) = \left[(xj - xi)^2 + (yj - yi)^2 + (zj - zi)^2\right]^{\frac{1}{2}} \tag{1}$$

3.2 Underwater Propagation Model

A water environment is an intricate and homogeneous environment; therefore, it is difficult to develop a mathematical model that considers all relevant physics parameters. The propagation delays are very high in UWSNs. To work with the communication model of UWSNs, we consider not only propagation delays but also attenuation due to absorption and spreading. The parameters that we have considered for our model are given below:

3.3 Speed of Sound

Another significant factor in acoustic media is the speed of sound. For most calculations, the speed of sound in water is taken to be approximately 1500 m/s. Although this is precise within a specific range, the submerged channel is affected by many unstable variables, such as temperature, salinity, and pressure. These elements may likewise be dependent or change over the numerous areas and depths of the sea. Thus, it is critical to implement an exact model of the effects of these parameters on the speed of sound in water. The speed of sound in water has been an important point of investigation in numerous scientific models [6–8]. A simplified form for the speed of sound is given below:

$$\begin{aligned} v = \{&1449 + 4.6t + 0.055t^2 - 5.304x10^{-2}t^2 + 2.374x10^{-4}t^3 + 1.630x10^{-2}d + 1.675x10^{-7}d^2 \\ &- 7.139x10^{-13}td^3 + 1.340(s - 35) - 1.025x10^{-2}t(s - 35) \end{aligned} \tag{2}$$

v = sound speed in m/s, t = temperature in degrees Celsius, s = salinity in parts per trillion (ppt), d = depth in meters.

Equation 2 shows that the speed of sound varies with temperature and according to changes in salinity and depth in water. It is clear that the speed of sound in water is not a constant, as the depth of sea is varies from 0 to 1500 m, the temperature and salinity of water decreases along with sound speed [6–8]. For our proposed shallow water model after the investigation from literature (6 to 8), this factor was taken as 1500 m/s.

3.3.1 Attenuation and Propagation Delay

Underwater sound proliferates at an estimated speed of 1500 m/s. Submerged attenuation of the signal occurs due to spreading and absorption losses of the communication channel. For a distance of 1 km from the source to the destination at frequency f (kHz) and spreading coefficient k, attenuation $A(d,f)$ can be calculated as described by Urick [8, 20]:

$$A(d,f) = d^k \vartheta^{\mathrm{d}} \tag{3}$$

where d = distance between source and destination, K = spreading factor (2 for spherical spreading and 1 for cylindrical spreading), Practical value of k = 1.5, ϑ is defined as

$$\vartheta = 10^{\alpha(f)/10} \tag{4}$$

ϑ is related to the absorption coefficient α. The absorption coefficient depends on the frequency and is calculated by Thorp's expression in [6] for frequencies above a few hundred Hertz as follows:

$$\alpha(f) = \frac{\frac{1}{10}f^2}{1+f^2} + \frac{40f^2}{41x10^2+f^2} + 2.75 * 10^{-4f^2} + \frac{3}{1000} \tag{5a}$$

For lower frequencies, α is expressed as follows:

$$\alpha(f) = \frac{11}{100} * \frac{f^2}{1+f^2} + \frac{11}{100}f^2 + \frac{2}{1000} \tag{5b}$$

where α(f) is in dB/km, and f is the frequency in kHz. The absorption coefficients of the proposed model are listed in Table 2.

3.4 Basic Communication Energy Consumption Model

Basic energy consumption is the most investigated issue of sensor networks and can be classified into three basic modules:

a. Sensing
b. Computation
c. Communication energy consumption

As observed, the communication energy cost of the network is larger than the computational cost, and turning off radio transceivers when necessary is one of the most efficient methods to prolong the network lifetime. Based on this concept, a number of energy-efficient schemes have been proposed. To investigate energy-efficient underwater

Table 2 Steps of proposed methodology

Initialization phase	Nodes are randomly drooped Set value of cluster head formation (P) and set threshold for Cluster head selection $T(i) = p/(1 - p(r mod 1/p)$ It's composed of a cycle made of 1/p rounds Each node computes threshold T(i) If xi ≤ T(i), then node i designates itself as CH for the current round Every node can become CH once in every cycle 1/p rounds Compute energy e_{Chsele}
CSMA	Cluster head (CH) broadcasts advertisement message with transmitted power P_0 Based on the received signal strength of advertisement, the rest of the nodes choose its CH for the current round All nodes send back a message to inform the considered CH Compute energies e_{CHadv} and $e_{nnoderadv}$
Time division multiple access (TDMA/CDMA)	CH setup transmission schedule and send transmission schedule to all its joint nodes CH keeps listening to all associated nodes All sensors send their data to the CH in turn When it's not other nodes turn, they remain in sleep mode Compute energies e_{CHC} and e_{NC}
Data compression/aggregation	CH receives data from all nodes in turn CH aggregates or compresses the data and sends them to base station Compute energye_{CH}.

communication, we modified the LEACH algorithm considering the underwater physical parameters. To analyze the applicability of our modified LEACH algorithm, we compare it with the conventional LEACH algorithm for terrestrial wireless sensor networks. The proposed approach has been found to be quite effective in terms of energy conservation and network life.

The energy consumption model for the terrestrial sensor network associated with the LEACH algorithm proposed by Heizelman is based on the following energy Eqs. (7) and (8) [5, 26, 30].

Terrestrial WSNs are usually composed of small battery power sensor networks, and their basic energy consumption model is based on the following equations:

- To transmit the x-bit through a distance d", the transmitter consumes

$$e_{tr}(x, d) = \{e_{elec}(x) + e_{amp}(x, d)(e_{elec} * x) + \left(e_{amp} * x * d^2\right) \tag{7}$$

- To receive an x-bit message, the receiver consumes

$$e_r(x) = \{e_{elec}(x)x * e_{elec} \tag{8}$$

where, $e_{tr}(x, d)$ and $e_r(x)$ represent the energy consumes for transmitting x bit through distance d and energy consume for receiving x bit respectively. e_{elec} and e_{amp} represent the energy of electronic transmission and amplification, respectively.

The basic UWSN acoustic communication model used for communication [5, 26] is as follows:

- To achieve a power level P_0 at the input to the receiver at distance d, the transmitted power needs to be [10, 30]

$$P_e = P_o * A(d,f) \tag{9}$$

- The energy consumption for x data transmission is

$$e_t(x, d) = x * e_{elec} + x * P_o * A(d,f) \tag{10}$$

- Sensor nodes consume energy to receive x bits of data

$$e_r(x) = x * e_{elec} \tag{11}$$

- Sensor nodes consume energy for idle listening

$$e_i = \beta * e_{elec} * x \tag{12}$$

where, e_{elec} = energy consumed by the electronics for transmitting and receiving 1 bit of data measured in (J/b), x = number of bits, β = ratio of reception and idle listening energy, P_0 = power level at receiver.

4 Proposed Methodology

This investigation is based on energy conservation hierarchical clustering-based systems for UWSNs. The basic objective of clustering is to extend the life of the network by adjusting the burden of nodes. Our proposed algorithm is a modified form of the LEACH algorithm.

As shown in Table 2 in this suggested dynamic clustering procedure, to preserve correspondence energy among all the nodes in each round, the cluster head is selected randomly. All the nodes have the equivalent chance of being chosen as the head of the cluster, and the cluster head (CH) decision is refreshed in every round. This is based on rounds, and each round includes two stages: a setup stage and a steady-state stage. In the setup stage, groups are formed, and the head of the group is chosen. In the steady-state stage, information from each cluster head CH moves to the sink at the apportioned schedule time.

In the setup period of each round, cluster head(CH) is chosen by considering the rate "p", which is an ideal percentage of cluster head (CH) for each round (r). In the system, every node “i” chooses an arbitrary number somewhere in the range of 0 to 1. At that point, if the number is less than the threshold limit T(i), as shown in Eq. (13), then that node pronounces itself as a CH for the current round. The chosen CH informs its neighbors about its selection, and all residual nodes choose their CH on the basis of least distance and residual energy.

$$T(i) = \frac{p}{(1 - px\left(rmod\left(\frac{1}{p}\right)\right)} \tag{13}$$

where, p is the probability of selecting the cluster head and r is the current round of clustering algorithm.

In the steady-state stage, each CH gathers sensed information from its cluster nodes and sends the total aggregated information to the base station. During this contention period, communication between the head of the cluster and its associated node is accomplished by non-persistent CSMA and throughput ρ is given as

$$\rho = \frac{k_c x e^{(-\xi x k_c)}}{k_c x(1 + 2\xi) + e^{(-\xi x k_c)}} \tag{13}$$

where, ξ is the ratio of the propagation delay to the packet transmission time. The critical value of the propagation delay for water is computed as

$$T_{propagation} = \frac{d_{distance \frac{b}{w} nodes}}{v} \tag{14}$$

where, v is the propagation speed of underwater sound and d is the distance between the sensor nodes.

Energy consumed in cluster head selection (CH to sink communication)

$$e_{CH\ sele} = \frac{x_c}{\rho} e_t + (\frac{(\text{ꞵ}xn-1)}{\rho}) e_i + e_r \tag{15}$$

All CHs broadcast their selection, and all associated nodes are listening nodes and retain the ON channel.

Energy consumption in broadcast CH selection advertisements and for N nodes to receive CH advertisements are shown in Eqs. (16) and (17), and the total energy consumption in CH selection and advertisements is shown in (18).

$$e_{CHadv} = x_c e_t \tag{16}$$

$$e_{N\ node\ r\ adv} = \text{ꞵ} * n * x_c * e_r \tag{17}$$

$$E_{T\ CH\ sele\ \&\ adv} = e_{CH\ sele} + e_{CH\ adv} + e_{N\ node\ r\ adv} \tag{18}$$

where,e_r = Energy consume in receiving information, e_t = energy consume in transmitting information, e_i = energy consume in idle listening, n = numbers of nodes.

Utilizing the time division multiple access protocol [11], every node in its allotted time sends its information to the CH. After this time, nodes end their transmission and become inert nodes until the next distributed schedule opens. The energies consumed in this contention phase on CH and n nodes are shown in Eqs. (19) and (20):

$$e_{CHC} = N * e_t + e_r \tag{19}$$

$$e_{NC} = \frac{x_c}{\rho} e_t + \frac{N-1}{\rho} e_r + e_i \tag{20}$$

The total energy consumed in the contention phase is

$$E_{TC} = e_{CHc} + e_{Nc} \tag{21}$$

All nodes send their sense data to the selected head of the cluster. The cluster head aggregates the received data and sends them to the sink. These operation energies consumed on the cluster head and associated nodes are calculated as follows:

$$e_{CH} = m * N_i * e_{t\ to\ CH} + (\mathbf{N} - N_i) * e_i + e_{t\ to\ sink} \tag{22}$$

where, N_i is the number of associated nodes and m is the number of frames. Details of the symbols used in Eqs. 15 to 22 are given in Table 3. e_t, e_r and e_i are calculated from Eqs. (9), (10) and (11).

Table 2 shows the steps of methodology of the proposed system.

In a given methodology, a diverse number of cluster heads can vary in each round depending on the value of p (percentage of CH selection). Furthermore, all the elected cluster heads can be located in the same region of the network, leaving uncovered areas with the expectation of improvement. This procedure is repeated in multiple rounds.

Details of the symbols used in the above equations are listed in Table 3.

4.1 Simulation Parameters

The proposed system is based on a Monte Carlo simulation to execute an energy-efficient solution. The MATLAB simulation tool is used for experimental data analysis, taking an average of 25 simulation results. The sink node is located in the center of an underwater 100 m × 100 m area of the network with uneven deployment of 50 nodes. Based on the 3D architecture of the UWSN, acoustic parameters are considered with a defined network depth of 75 m. The simulation parameters are listed in Table 4. The algorithms for the UWSN and WSN are implemented in the same simulation platform, and the results are compared.

5 Experimental Results and Analysis

The performance of the proposed algorithm was evaluated using simulation.

First, the energy model for hierarchical and random cluster base networks was developed in MATLAB for UWSNs and for terrestrial WSNs. The proposed algorithm was implemented with the energy model presented above in section 3 in Table 2 of the paper for the UWSN. Conventional LEACH was implemented with the energy consumption model mentioned in section III of the paper for terrestrial WSNs. Second, by considering the lifetime and residual energy run simulation model of UWSNs and terrestrial WSNs for

Table 3 Details of symbols used in the proposed methodology

e_{Chsele}	Energy consumed in cluster head selection
e_{chadv}	Energy consumed in cluster head advertisement
$e_{nnoderadv}$	Energy consumed in receiving advertisement of cluster head at n nodes
$E_{tChsele\&adv}$	Total energy consumed in cluster head setup phase
e_{ChC}	Energy consumed in contention phase at cluster head
e_{NC}	Energy consumed at number of N nodes
E_{tC}	Total energy consumed during contention phase
e_{Ch}	Energy consumed for data collection from all N nodes, aggregation and sending to sink
N	Number of nodes
N_i	Number of associated nodes
m	Number of frames

Table 4 Details of parameters used in simulation

	Value
Field dimension	100 m, 100 m
Number of nodes	50
Optimal election probability of CH (percentage of desired clusters)	10
Location of BS	(0,0,0)
Initial energy (UWSN)	5 J
Initial energy (WSN)	2.5 J
E_{elec}	50 nJ/bit
α (f)	1.001
Carrier frequency of acoustic signal	25 kHz
V(T,S,D) m/s	1500
Absorption factor (α)	0.001

different numbers of rounds, we compute the performance parameter and compare the efficiency of both networks.

Figure 2 compares the energy consumption for the UWSN and WSN, Fig. 3 shows the number of a node that die per round in the network, which represents the life of the network, and Fig. 4 shows the life of the network.

Figure 2 shows that the energy consumption of the network progressively increases as the number of rounds increases, and at a certain round number of 1300, the energy consumption of both the UWSN and WSN is approximately the same: 93.2% for the UWSN and 92.8% for the WSN. At approximately 1400 rounds, the values of energy consumption are 95.41% for the UWSN and 95.82% for the WSN**.** The difference is 0.41, which is very low and can be ignore.

Regarding the lifetime of the network in Fig. 4, we note that in the WSN at 100 rounds, 4 nodes of the network are dead, while in the UWSN, 5 nodes are dead. The lifespan gradually increases with the increase in rounds. In round 1300, the number of dead nodes is 47 in the UWSN, while in the WSN, the number of dead nodes is 48. In round 1400, the onward pattern and number of failures of nodes are the same. This shows that our proposed algorithm works as well in UWSNs as conventional LEACH in terrestrial WSNs.

From close observation, it is found that the patterns of network failure and energy consumption in UWSNs are the same as those in TWSNs. Small changes are required; for

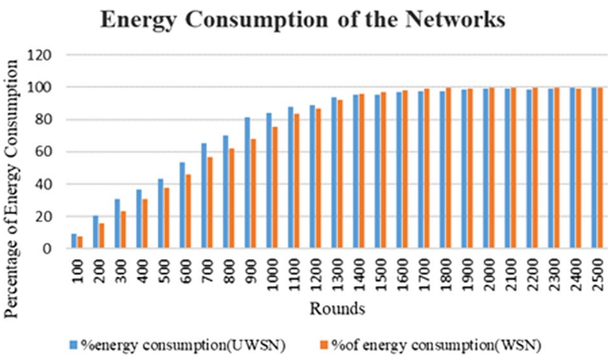


Fig. 2 Energy consumption of the UWSNs and the WSNs

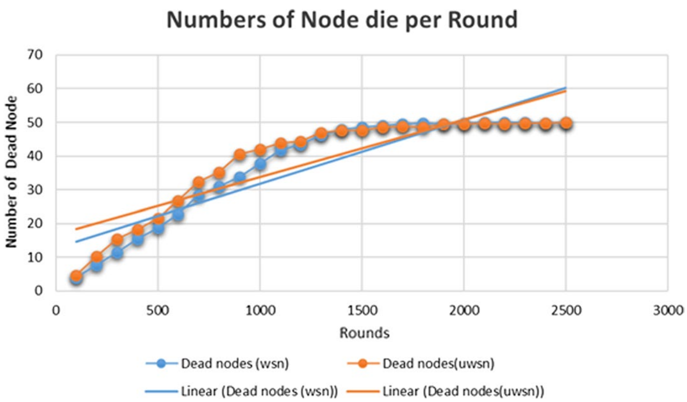


Fig. 3 Numbers of dead nodes in the UWSNs and WSNs

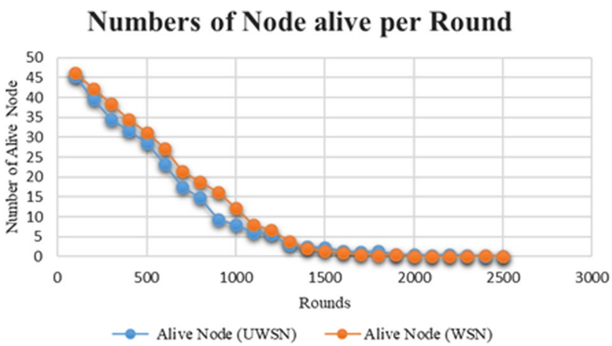
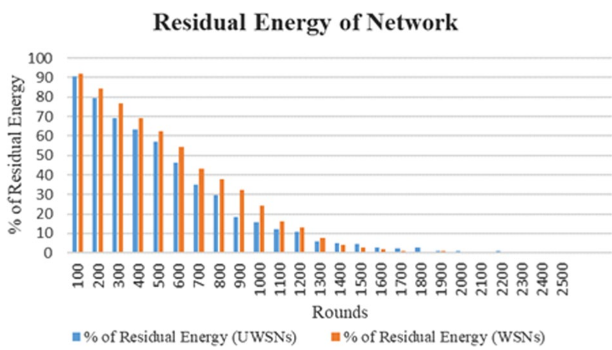


Fig. 4 Life of the network

Fig. 5 Residual energy of the network



example, if we increase the battery power of a UWSN by 1/3, then we can extend the life of the network or balance the load of the system.

As shown in Fig. 5, our proposed conventional system has a decreasing pattern of residual energy with respect to the number of rounds, and this result is the same as in conventional LEACH for terrestrial WSNs, with mean residual percentages of 23.72 (UWSN) and

25.07 (WSN). This shows that there is no immense difference, and the proposed algorithm is appropriate for UWSNs as conventional LEACH for terrestrial WSNs.

6 Conclusion and Future Work

Both underwater and terrestrial networks organize sensors that are powered by a constrained energy source. In any case, energy preservation is a significant issue that must be considered to build a mechanism that allows the network to extend the life of the system. A modified form of the LEACH algorithm was proposed for underwater communications. The experimental outcomes of the immediate correspondence of the proposed approach demonstrate that adequate energy utilization increases the system lifetime of underwater sensor networks, such as conventional LEACH in terrestrial WSNs. This shows that the energy model for hierarchical clustering and random cluster head selection of conventional LEACH can be applicable underwater with the consideration of underwater environmental parameters. In future work, we will propose an approach with a 3D layered multihop clustering convention utilized in an underwater sensor network and will demonstrate this approach by considering different distinctive parameters of the network.

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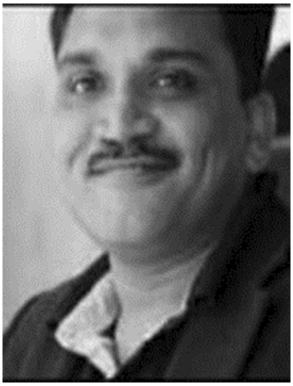

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