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Adaptive Energy Efficient Circular Spinning Protocol for Dynamic Cluster Based UWSNs

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ABSTRACT Under Water Sensor Network (UWSN) is a novel paradigm for exploring marine environments such as offshore and mineral exploration, underwater surveillance, and sea habitat monitoring. However, a good quality underwater communication is difficult to achieve due to different constraints such as limited bandwidth, acoustic propagation issues, delays, battery replacement hitches, etc. In recent works, efficient energy-based designing and overall performance evaluation of the UWSN has become a major consideration. Cluster-based sensor networks have proven to be a successful way to increase the network's load congruency and scalability while lowering the system's total energy consumption. Usually, clustering algorithms work in three phases; cluster setup, data collection, and transmission to sink. In these types of dynamic cluster-based networks, energy consumed in cluster setup has been considered insignificant. Since these network energy consumptions are not part of data communication, we consider it extra energy consumption. In this paper, a new Energy Efficient Circular Spinning (EECS) dynamic clustering algorithm has been proposed to provide an improved cluster setup system and to minimize energy usage in re-clustering or cluster setup. Our proposed EECS mechanism suggests that system performance can improve by reducing the Cluster Head (CH) selection phase or cluster setup phase and can ultimately minimize the energy consumption of networks. It is demonstrated that by reducing the transmission of superfluous control messages during the cluster arrangement stage, approximately 21.5% to28.4% of the total network energy expended can be saved. This paper also compares the extra energy consumption, total network energy consumption, and life of the network in our proposed EECS mechanism to two different mechanisms, (1) Adaptive LEACH for UW, (2) UMOD_LEACH. The optimum value of cluster head has been calculated from energy consumption of different protocols and results show that our proposed EECS can prolong network lifetime by 21.5% and 28.4%from the above-mentioned algorithms consequently. In future, we will extend outwork for multi-hop dynamic cluster base mechanism for UW.

INDEX TERMS Extra energy, energy efficient circular spinning method, re-clustering.

I. INTRODUCTION

Dynamic clustering mechanisms in UWSNs work hierarchically as shown in Figure 1. In the setup phase of Dynamic clustering mechanisms, cluster heads are selected, and clusters are formed with neighboring associated nodes. These mechanisms not only provide scalability of the network but also limit energy consumption and extend the lifetime of the network. In dynamic clustering algorithms, the selection of cluster head is the critical task, and the majority of researchers have proposed clustering protocols based on different criteria of cluster head (CH) selection [1], [12], [35]. Different authors, by using adaptive, deterministic, centrally controlled, or randomly selected cluster heads, have proposed different energy-efficient protocols for WSNs as well as for UWSNs [5]–[14]. But a very few of them have considered the energy consumption during cluster setup of the networks. In dynamic cluster-based networks, to get a reasonable

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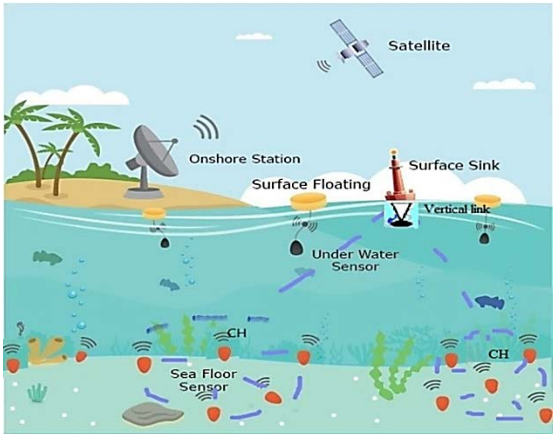

FIGURE 1. Dynamic cluster based underwater sensor networks.

distribution of energy utilization throughout the network, the responsibility of the cluster head (CH) revolves among various nodes of the cluster. The selection of cluster heads may depend upon certain criteria. However, this repeated selection of cluster head and cluster formation performs transmission of control packets and consumes the energy of the networks. This energy consumption is the extra energy consumption of the network because it is consumed in the setup of the cluster instead of the transmission of data.

In this paper, our main emphasis is on the cluster head selection phase and the determination of extra energy usage in this phase. After computing extra energy we have also proposed the Energy Efficient Circular Spinning protocol (EECSP) for the dynamic cluster-based UWSNs to reduce the extra energy consumption of the network. EECSP reduces the excessive transmission of control packets in the cluster setup phase, hence reducing the extra energy consumption. Although energy calculation and execution of our algorithm have been done according to LEACH protocol, our basic approach can be applied in any dynamic cluster-based algorithm. EECSP is specifically, appropriate for those distributive algorithms where cluster head selection is random.

The remaining paper is divided into the following sections. Section 2 represents the literature review, section 3 explains the energy consumption in data collection, section 4 explains the details of the proposed circular spinning protocol, section 5 gives the simulation methodology, section 6 evaluation of EECS and section 7 gives results and analysis and section 8 concludes the paper.

II. LITERATURE REVIEW

Problems and procedures of clustering algorithms have been extensively reconnoitered for terrestrial WSNs (1- 7) and UWSNs (8-17). Though, the issue of network connectivity due to the cluster-head failures has not been well addressed, in particular, for UWSNs. An archetypal resolution to this problem is re-clustering [2]. However, using the re-clustering process repeatedly will be costly due to the messages exchanged for cluster formation. This phenomenon will affect the timeliness and reliability of the data exchanged between sensors and the cluster heads. It will result in a more energy-intensive and unreliable system [9]–[11]. Based on the literature review the methodologies for CH selection in the cluster setup stage can be divided into three categories random, adaptive, and centrally controlled or deterministic. Literature review of the selection of CH of different schemes is given below:

A. RANDOM CH SELECTION

Heinzelman *et al.* [2], proposed Low-Energy Adaptive Clustering Hierarchy (LEACH). It is a conventional algorithm in hierarchical networks. For uniform distribution of energy consumption, he randomly chooses the cluster head in a cyclic routine in every different round. His strategy facilitates efficient energy consumption but neglects the information of the nodes when selecting the CH nodes, i.e., residual energy, the energy depletion of communication, and the number of the associated nodes. Djamel Mansouri *et al.* [3] proposed a modified LEACH algorithm for underwater acoustic sensor networks. He applied the dynamic clustering process, to the energy consumption model of acoustic communication and shows the applicability of LEACH in UWSNs with the consideration of acoustic parameters. Kyeong Mi Noh [4] proposed as D-LEACH and divides the networks into layers. In each layer probability of cluster head formation are different. The cluster head selection probability of the upper layer is higher than the lower layer. Mohapatra *et al.* [5] worked on PE- LEACH algorithm with the random rotational selection of CH, it is also an extended form of LEACH and to some extent overcome the limitation of the LEACH algorithm.

B. ADAPTIVE CH SELECTION

The criteria of an adaptive algorithm for cluster heads are capricious and adapt to the quantity of resources available at that time like energy level, signal strength, distances [6]–[9], and fitness function of nodes. Xia Li *et al.* [10] worked on the updated form of LEACH and adopt the local controlling methodology and set the probability the node that has chosen the header node previously act as the header again is zero, and the node that has more remaining energy will be elected as the new cluster header. The newly elected header node computes its cluster based on coverage and excludes the nodes that have moved out of the cluster, adding the nodes that transfer in the cluster recently. Khan. M.F *et al.* [13] worked on a ‘‘dragonfly optimization’’ (DFO) algorithm and select the best clusters heads (CH) base on fitness function while [14], [15] used fussy logic to select the best CH for each round. S. A. Sert *et al.* [16] proposed Two Tier Distributed Fuzzy logic based protocol (TTDFP) to extend the life span of multi hop WSN and taking into account the efficiency of clustering and routing phases jointly. It is a distributed adaptive multi hop protocol that runs and scales efficiently for sensor network applications.

Guangzhong Liu *et al.* [17] Improves election of cluster head by energy weighing algorithm and assign a weight to nodes according to the residual energy. The cluster head has been selected based on the ratio of initial energy to residual energy. A. S. Alhazmi *et al.* proposed UMOD-LEACH [18], a modified form LEACH protocol, and elect cluster head randomly based on residual energy and location of nodes. The UMOD-LEACH beat LEACH, on average more than 30% for the maximum 70% of the amount of transmitted data. On the other hand, the energy consumption for a small amount of data, the protocols almost performed the same as LEACH. Sunil Kumar Singh *et al.* [19] proposed a novel strategy using unequal fixed grid-based cluster along with a mobile data mule for data collection from the cluster head (CH). In his strategy CH is selected on the bases of minimum cumulative transmission distance for member nodes within the cluster and he also has endeavored to optimize CH change time or round number.

To extend the life and reliability of the network, Anupama *et al.* [20] suggested a clustering algorithm based on the geographical location of sensor nodes for 3D- hierarchical architecture. In his structure, the sensor nodes are deployed at fixed relative depths to each other. Then clusters are formed with multiple CH at each tier with its associated nodes. The cluster head is selected based on the position of the sensor nodes, residual energy, and more memory in the cluster. Then, selected CH collect data and forward it to the sink with the assistance of an acoustic underwater vehicle (AUV). Wan Z *et al.* [21] proposed a multilevel ACUN for underwater networks, and selection of CH has taken place based on residual energy of node and shortest distance to the transmission. Xiao. X *et al.* [22] proposed EECRP Based on Data Fusion and Genetic Algorithm and introduced an optimized CHN selecting scheme considering residual energy and positions of nodes.

C. SELECTION OF ADAPTIVE ADDITIONAL BACKUP CH OR VICE CH WITH CLUSTER HEAD

To minimize re-clustering and save network energy [23]–[28] Proposed clustering protocol endeavors to select a primary cluster head with a backup cluster head for each cluster during clustering. In this way, the constructed cluster network can overcome any cluster-head failure. G. Yang *et al.* [23] also, select a backup cluster with a cluster head in terms of operational capability and residual energy. All node sense information and sent to the head node is also saved in backup nodes. The backup nodes also periodically check the state of the cluster head node. In case of a software or hardware problem in a cluster head, one of the nearby backup nodes switches it and functions as a new head node. The drawback of this algorithm is the use of resources and simultaneous and continuous use of storage from both the primary and the backup CH node. C. Huang *et al.* [24], also used backup CH and introduce a checkpoint scheme to store the state of CH and ensure connectivity. In case of failure, it further proposed a repair efficiency scheme. To extend the life of the network and stability of the network Hong Min *et al.* [25] also elects vice cluster with the election of CH for his proposed energy-efficient clustering protocol.

Sanjeev Kumar *et al.* [26] proposed a cluster head selection algorithm based on the distance, the maximum energy, and connectivity level between the nodes select vice cluster head with cluster head. In his scheme, the vice cluster head has elected with cluster head election according to the minimum distance and maximum energy. The vice cluster head is activated only when the cluster head dies and maintains continuous communications. However, the availability of intermediate CH in case of the distance between vice CH and BS more than transmission is impractical and remedy of this situation is not discussed.

S.K Murugaraja *et al.* and K. Ovaliadis [27], [28], also attempt to select a backup cluster head simultaneously with the selection of primary CH for each cluster. By this scheme, the assembled cluster network can adjust any cluster-head failure. In each cluster, every cluster member can check the heartbeats periodically sent by the CH and identify the state of its cluster head. In case of failure of cluster head, the members of the failed cluster group can quickly change over to the backup cluster head. In this manner, the connectivity member nodes to the sink resume without waiting for re-clustering to execute. The scheme [27] is vain to state clearly recovery process while the scheme [28] not only state CH failure detection procedure but also define the recovery procedure of CH.

D. DETERMINISTIC CH SELECTION (COURIER NODES USED TO COLLECT DATA AS CH)

Many researchers work on predetermine or centrally control cluster head schemes and implanted externally CH to the cluster.

Ayaz *et al.* [29], proposed TCBR algorithm. In his scheme three kinds of nodes are used: ordinary sensor nodes and some special sensor nodes called courier nodes. Cluster ordinary sensor nodes sense and collect data and forward these data to a closer courier sensor node. Courier sensor nodes collect this data and send data to a surface sink. Every courier node is assembled with a mechanical module; a piston, which can create positive and negative buoyancy. This module helps the node to move inside the water at different predefined depths and then pull them back to the sea surface. These courier nodes, reach different depth levels, stop for a specified period, and then broadcast hello packets to discover any ordinary nodes around them. The ordinary nodes receive more than one of these messages it will forward the data packet to the closer courier node. However, data can be collected when a courier node is inside the communication range of every sensor node. Because of this, all the sensor nodes will keep their data packets in a limited buffer until a courier node reaches them. Despite this feature, the TCBR is not suitable for time-critical applications.

Sarang Karim *et al.* [30] proposed ANCRP, and for reliable data transfer and avoiding void holes he divides the networks into small cubes, and in each cube, a cluster is formed. Further, each cube was assigned with the anchor node as a CH. All CHs were supposed to be an anchor in the middle of each cube via a string and all other sensor nodes were distributed randomly. Each designated CH collects data from sensor nodes of its cluster and transmits it to the next hop CH and this procedure continues till the data packet is transferred to the sink. He further proposed VH-ANCRP for avoiding void holes. Although this technique is suitable for small networks and the further author uses a courier node without assistance which is impossible to manage in the UW environment. Ahmed *et al.* [31] proposed a Cluster-based energy-efficient routing protocol (CBE2R) designed for the underwater environment. He divided the oceanic depth into seven layers. On each layer, courier powerful nodes are implanted from top to bottom to increase the battery power of nodes. Courier nodes are called CH, form a cluster and gather information from sensor nodes and send it to the base node. These courier nodes have more energy and memory as compared to sensor nodes. Another clustering approach is CMSE2R, Mukhtiar Ahmed *et al.* [32] proposed CMSE2R protocol; it is a cluster-based multipath shortest distance energy-efficient routing for UWSNs. CMSE2R is based on four stages the first stage is network setting, the second stage is cluster creation, the third stage is multipath growth in the related clusters and the last stage is the transfer of data. He further introduced three types of nodes CN (courier node) forwarding node (FN) and sensor nodes (SN). The CN sends a hello packet to the FN and becomes a CH. FN around CN forward data of SN to the CN. Finally, CN sends data to the base station. In this work by designating different function to three types of node author claim to increase the reliability of the link while in my opinion, his proposed scheme is not only expensive but also a complicated mechanism.

E. CLUSTERING ISSUES

The main objective of clustering is to balance the load of energy consumption between cluster head and cluster members and maintain the synchronization of the network [33]–[37]. It can be accomplished by periodical re-clustering and cyclically selecting a random cluster head. Though, the cost of the re-clustering affects the protocol's oration, the period of this process needs more, in-depth attention. As an alternative to a fixed period of re-clustering, an adaptive criterion can be used. For example, a re-clustering period can be taken into account based on the mobility of the nodes or the number of redundant transmissions. Another concern of these algorithms' performance is that they are reliant on the device discovery time, i.e., the time taken by a node to discover and to connect to another node in its range. The time it takes to complete the construction of the cluster team is critical for an efficient cluster algorithm, especially when the number of sensor nodes is significant. Delays in the initial cluster setup phase result in additional packet transmissions and higher power usage.

To reduce this overhead several researchers present their efforts to reduce re-clustering. The adaptive protocols [23]–[28] discussed above have selected the primary or advisor cluster head with the selection of cluster head to manage the malfunctioning failure of cluster head or to minimize the CH selection phase. Numerous recent works [29]–[32] have embedded courier nodes or carrier nodes as CH and completely avoid the CH selection phase. This technology reduces the overall power consumption of sensors in the cluster, but it complicates network deployment because the network uses two different types of sensor nodes and must plan the CH placements before placing them into the cluster. There's also a chance that one parameter will skew the fitness function, resulting in inappropriate CH deployment, which will impair network functionality and longevity.

To summarize, the existing algorithms described above make an effort to avoid re-clustering, thereby saving energy in cluster construction and extending network life, however, some concerns need to be investigated further. These systems are costly, and they necessitate a certain sort of courier/carrier or rely on not only AUV but also require extra supervision. Furthermore, these algorithms do not ensure that all network nodes are synchronized regularly and after some time, a disrupted condition can be established due to a loss of synchronization. Another issue is due to the random deployment of nodes these algorithms can't guarantee uniformity in cluster size. This can create an unbalanced load of communication on some of the nodes and then these nodes die earlier than others.

In the next section the idea of decreasing the energy in the cluster setup stage is discussed. It is done by limiting cluster formation in the network life and then spinning the role of CH among different nodes of the cluster. Our proposed circular spinning strategy conserves energy during the CH establishment phase, however, to preserve cluster uniformity, our scheme does not totally prevent the process of re-clustering. There is no one-time formation of clusters therefore circular spine method can maintain periodical synchronization and balance load of communication.

III. ENERGY CONSUMPTION IN THE STEADY-STATE PHASE

Re-clustering is conducted regularly in each cycle of the dynamic cluster protocol. This process necessitates the transmission of control packets. The energy consumed for this setup is referred to as the network's extra energy expenditure and use future technologies such as Software Defined Networking (SDN) [39]–[43]. In earlier work, the majority of researchers took it lightly, and others avoided it entirely. In this research, we not only estimate the amount of energy consumed during the cluster setup phase, but we also provide a way to reduce it. In the following section, we describe a strategy that does not circumvent re-clustering while also demonstrating a significant reduction in additional energy in dynamic cluster base UWSNs.

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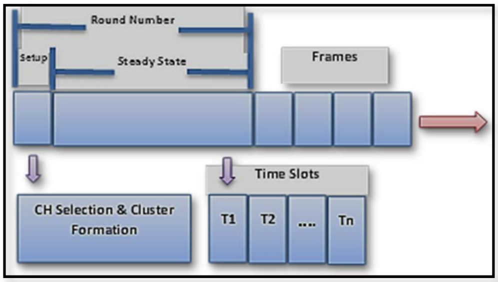

FIGURE 2. Random cluster head selection protocol.

TABLE 1. Transmission ranges.

Transmission Ranges	Description
D_{max}	The maximum distance between the CH and the end of the field. This distance is used to calculate the energy consumed in the broadcast of the CH advertisement.
$D_{to\ CH}$	The distance between the associated node and the CH. It is used for energy consumption used for sending data to CH.
$D_{to\ Sink}$	The distance between each CH to the sink. It is used for energy consumption used for transmitted from CH to sink.

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Low energy adaptive clustering hierarchy (LEACH) has been used as a basic example to explain the basic operational working and energy consumption pattern of the dynamic clustering protocol. Then we explain how our energy-efficient circular spinning protocol (EESCP) works, which can be used not just with LEACH but also with any dynamic clustering technique. Our EECS functions in a single hop in such a way that every selected CH in each round in UWSNs collect data from its associated nodes and transfer its data to the BS and therefore the CH accepts the responsibility of sending information to the entire network. The LEACH protocol is divided into three phases: setup, steady-state, and data transfer (see Figure 2). The actual data transmission process is the collection of data from sensor nodes and transfers to their cluster heads and after aggregation on the cluster head, send to the base station other than this all exchange of data during setup consider as an encumbrance and extra energy consume in these phases. In our proposed algorithm we called it Extra Energy (E_{extra}) consumption.

A. EXTRA ENERGY CONSUMPTION MODEL OF UWSNs

Due to the underwater acoustic channel, the energy consumption model of UWSNs is quite different than the WSNs. The energy consumption model developed for the calculation of E_{extra} based on the following energy equations given below

Energy consumed for transmission of data

$$E_t(x,d) = x * E_{ele} + x * P_e \tag{1}$$

where: E_{ele} = Energy consumed by the electronics for transmitting and receiving of 1-bit data measured in (j/b)

x = number of bits and

P_e defined as,

$$P_e = P_o * A(d,f) \tag{2}$$

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

where d is the distance between transmitter and receiver and k is the Spreading factor (for spherical spreading is 2 and for cylindrical spreading is1)

The practical value of k is 1.5 and Po is the power threshold that the data can be received by the node. and ϑ is defined as

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

where α is the absorption coefficient and it is the function of the frequency and calculated from Thorp's expression [36] for the frequencies above a few hundred Hertz as:

$$f(\alpha) = \frac{0.11f^2}{1+f^2} + \frac{44f^2}{4100+f^2} + 0.275X10^{-5}f^2 + \frac{3}{1000} \tag{5}$$

Sensor nodes consume energy to receive x bits of data

$$Er(x) = x * E_{ele} \tag{6}$$

Sensor nodes consume energy for idle listening

$$EI = \beta * Eele * x \tag{7}$$

where $= \beta$ ratio of reception and idle listening energy.

B. DETAIL OF PARAMETERS USED IN ANALYSIS OF EXTRA ENERGY CONSUMPTION

In our simulation-based investigation, the Extra energy consumption has been considered carefully. At each step of each round, consider the transmissions of data and control packets. For different sizes of the network and the different numbers of the sensor node, the energy consumed in the cluster setup phase was calculated carefully. It can be inferred from the energy equations (1) and (6) for the data transmissions and receptions respectively, two factors dominantly affect the energy consumptions i.e. the distances between the transmitters and receivers (Transmission ranges) and the number of bits in data packets (Packet size)

For analysis, we have used three types of transmission ranges for transmitter and receiver separately shown in Table 1 and parameter and their values are shown in Table 2.

During the contention phase, the communication between the cluster head and all nodes is accomplished by non-persistent CSMA. ρ is the throughput of non-persistence CSMA can be represented as [44]

$$\rho = \frac{k_c X e^{(-\zeta * X_c)}}{X_c X (1+2\zeta) + e^{(-\zeta * X_c)}} \tag{8}$$

TABLE 2. Detail of parameters used in the simulation.

Simulation Parameters	Default Values
Size of the region (m x m)	50X50 100X100 200X200
Number of sensor nodes	50,100,200
Number of the sink node	1
Maximum transmission radius (m)	87
Acoustic speed (m/s)	1500
Propagation delay (Sec)	0.00066
Transmission time (Sec)	2.9
Absorption factor	1.001
Power level P_0 at the receiver	0.1x10-8
Frequency of carrier acoustic signal (KHZ)	25
The initial energy of nodes E_o (joules)	5
Data packet size K_d	250 Bytes
Control message K_c	25 Bytes
TDMA schedule packet size X_t	$(K_c$+N)x Bytes
Number of nodes/cluster N	Variable
Number of data frames/rounds m	10,50,100

In the above equation, X_c is the control packet size and ζ is a ratio of propagation delay and transmission delay. And these are the most critical factors for communication in UWSN, Propagation delay is the time kept by the signal for transmission from sender to receiver node in the network. As represented in equation (9), propagation delay t_p be influenced by the speed of sound and the distance between two nodes underwater [44], [45].

$$t_p = \frac{s}{v} \tag{9}$$

For our model underwater propagation speed is taken as 1500 m/s. It is mentioned in the previous work that as the depth of the sea is varied from 0 meters to 1500 meters, the salinity of water and temperature, decreases, along with the sound speed while propagation delay is increased [44], [45].

Transmission loss\ transmission delay is the effective parameter for UW communication. It weakened the sound strength through the path from the transmitting node to receiving node in the network. Transmission loss is determined by the transmission range and attenuation [11]. According to the thorp formula of attenuation, transmission loss is expressed in dB as [36]:

$$T_l = 20 \log r + f(\alpha) X10^{-3} \tag{10}$$

where $f(\alpha)$ is computed from the above equation and r is the transmission range in meter.

In our model speed of sound is 1500m/s and propagation delay is computed by using end to end delay model and it is 0.00066 sec for 1 m, from equation (9) and the value of parameter ζ taken as 0.00022 determine from equation (11) where transmission time is 2.9 sec [44]

$$\zeta = \frac{t_p}{T_t} \tag{11}$$

For a control packet size X_c of 25 Bytes, throughput for non-persistent CSMA ρ is 0.95. For our simulations, we have considered the values of E_{ele} as 50 nJ/bits (Because this value has been considered in many previous types of research/simulations). We have also considered that initially, each node (at its full capacity) has its energy as 5 joules. $\beta = 0.8$ is the ratio of energies consumed in data reception and idle listening modes [32], [33].

C. SIMULATION MODEL FOR EXTRA ENERGY CALCULATION

In this section, we present our model, which we used to calculate encumbrance energy called extra energy of dynamic clustering routing protocol.

We used MATLAB to experiment. MATLAB is a simulator that can be applied to WNS and UWSNs. Basic assumptions are given below

- The underwater sensor network is shallow water of a depth of 75 km.
- Area of the network 100 × 100 m ‘, 200 × 200
- The number of nodes distributed are 50,100 and 200
- Underwater acoustic sensors are distributed at random within the marine environment.
- The acoustic sensor nodes are static and secured to a base of sea stays.
- There is only one Sink Node in the network, which is the destination node placed at the center of network and has energy supplies. Nevertheless, underwater sensor nodes have limited energy and they do not have energy supplies.
- Sink at sea surface consist of two communication links, acoustic and radio, acoustic link dip into water and communicate and received data from acoustic sensor networks while radio link communicates and transmitted underwater collected data to the onshore station.
- All underwater sensor nodes have the equal initial energy of E_0 and the unique IDs
- Based on the received signal strength receiving nodes can estimate the distances to the transmitting node.
- The nodes can adjust their transmitting power levels according to the distances to their receiving nodes.
- Each underwater sensor node sense data and sends it to the selected CH node which can forward to sink nodes.

In this simulation, the effect of Extra energy on network lifetime has been considered. The network lifetime is defined as the first node of the network that has dead has calculated. The optimum value of the cluster head formation has been determined by varying the number of nodes, area of networks, and initial energy of the network.

In dynamic clustering advertisement of broadcast has done in non-persistent CSMA while in TDMA schedule data transferred to the destination.

TABLE 3. Details of energy consumption variable involve in clustering.

Variable	Detail of variables
$E_{CH\ sel}$	Energy consumption in CH selection phase
$E_{CH\ adv}$	Energy consumption in the CH advertisement phase
$E_{CH\ con}$	Energy consumes in the CH contention phase
$E_{CH\ f}$	Energy consumed in transmission and reception of data frame
$E_{N\ adv}$	Energy consumes at node in advertisement phase
$E_{N\ con}$	Energy consumes at node in contention phase
$E_{m\ f}$	Energy consumes in m data frame transmission

The parameters used in this simulation are given in Table 2 and the detail of the energy consumption variable involved in three phases of clustering are given in Table 3.

All energies mention above except energies consumed in transmitting m data frame in each cluster and sending this aggregated data to the sink are considered as Extra energy consumption of the network.

D. MATHEMATICAL MODEL OF ENERGY CONSUMPTION

Mathematical models of energy consumption for Cluster setup and data communication are given below:

Energy consumption for CH selection:

$$E_{CHselec} = \sum_{i=1}^{j} \{ \left(\frac{x_c}{\alpha}\right) \left[E_{ele} + P_o(D_{tosink})^k \vartheta^{D_{tosink}}\right] + \left(\frac{(pn-1)}{\alpha}\right)(x_c E_{ele}\beta) + x_t E_{ele} \quad (12)$$

Energy consumed at CH for broadcasting its advertisement to its associated nodes

$$E_{CHAdv} = \sum_{i=1}^{j} \{x_c(E_{ele} + P_o(D_{max})^k \vartheta^{D_{max}}) \quad (13)$$

Energy consumed in CH sends TDMA schedule to its nodes.

$$E_{CHcont} = \sum_{i=1}^{j} \{N x_c E_{ele} + x_t(E_{ele} + P_o(D_{max})^k \vartheta^{D_{max}}\} \quad (14)$$

$$E_{CHframe} = \sum_{i=1}^{j} \{m N_i x_d E_{ele} + (N - N_i)\,\beta x_d E_{ele} + x_d(E_{ele} + P_0(D_{tosink})^k \vartheta^{D_{tosink}}\} \quad (15)$$

Energy consumed by associated nodes (N_t) in each round is given by Eqs. 16-18. Where N_t is the number of nodes in an ith cluster in each round, where t = 1; 2; 3; k and k is the number of clusters in that round. Ni is the number of those associated nodes who have to send the data in this round. For our simulation purpose, Ni is taken randomly, m is the number of frames.

$$E_{NAdv} = \sum_{t=1}^{k} \sum_{i=1}^{N_t} \{pnx_c E_{ele}\} \quad (16)$$

$$E_{Ncont} = \sum_{t=1}^{k} \sum_{i=1}^{j} \{\frac{x_c}{\alpha}(E_{ele} + P_o(D_{toCH})^k \vartheta^{D_{toCH}}) + \frac{N-1}{\propto} x_c \beta E_{ele} + x_t E_{ele}\} \quad (17)$$

$$E_{Nframe} = \sum_{t=1}^{k} \sum_{i=1}^{j} \{m x_d(E_{ele} + P_o(D_{toCH})^k \vartheta^{D_{toCH}})\} \quad (18)$$

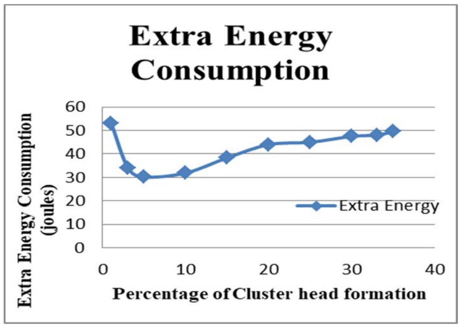

FIGURE 3. Extra energy consumption of the network.

The Extra Energy consumed on each node in r rounds are:

$$E_{Extra} = \sum_{r=1}^{R} E_{CHselecr} + E_{CHAdvr} + E_{CHcontr} + E_{NAdvr} + E_{Ncontr} \quad (19)$$

The Efficient Energy consumed on each node in r rounds are:

$$E_{Efficient} = \sum_{r=1}^{R} (E_{Chframer} + E_{Nframer}) \quad (20)$$

Total energy consumed in r rounds

$$E_{Total} = E_{Efficient} + E_{Extra} \quad (21)$$

E. ANALYSIS AND FINDING

Energy model for random cluster selection procedure built-in MATLAB for UWSN for extra energy computation. The simulation is run 1000 times with varied values of cluster head formation, and it is discovered that extra energy increases as the percentage of cluster head formation increase as shown in Figure 3.

To show the effect of extra energy consumption, in Figure. 4 maximum extra energy consumption is 15.2% of total energy at 1% of cluster head formation and it will affect the life of the network and the minimum extra consumption of energy is 9% at 5% of CH formation. Figure 4 also shows the difference between efficient energy and total energy of networks and the maximum difference of energy is 53.2 joules at 1% CH formation and the minimum is 30.2 joules at 5% CH formation. This amount of energy is countable and by efficient management of proposed EECS of reducing extra energy, we can conserve energy consumption and prolong network life.

IV. ADAPTIVE ENERGY-EFFICIENT CIRCULAR SPINING ALGORITHM (EECS ALGORITHM)

We proposed an energy-efficient Circular Spinning (EECS) mechanism for decreasing cluster setup energy of the dynamic cluster base protocol of UWSNs following the calculation of Extra Energy.

After the estimation of Extra Energy, we have developed an energy-efficient Circular Spinning (EECS) mechanism for minimizing cluster setup energy of the dynamic cluster base protocol of UWSNs is shown in Figure 5. Setup, steady-state, and data transmission are the three phases of a typical

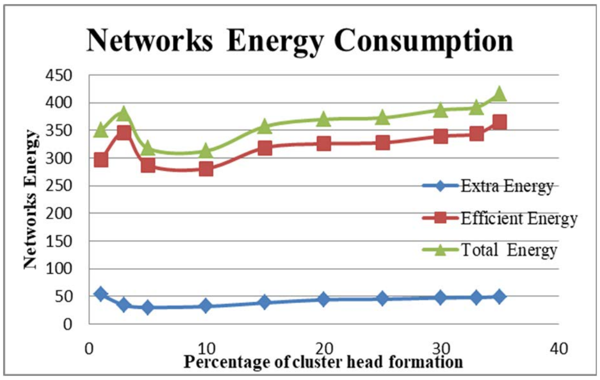

FIGURE 4. Energy consumption of the networks.

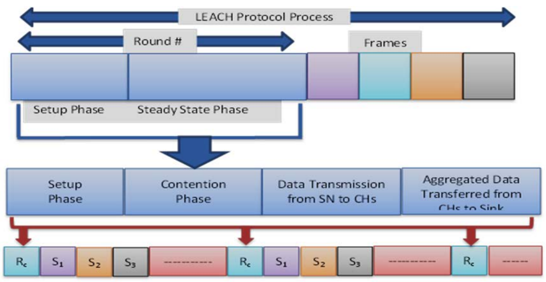

FIGURE 5. The setting of rounds of the proposed circular spinning method.

dynamic cluster base routing method. The data transmission intervals are divided into rounds, with CH selection and cluster creation performed repeatedly in each round. We calculated the amount of energy consumed in each stage of the rounds in this study. After estimating the cluster setup energy, we attempted to reduce it because, as previously stated, this phase is not engaged in data transmission. The majority of researchers entirely bypassed this phase by using externally integrated CH, which may lack network node synchronization. Our proposed methodology does not obviate the necessity of re-clustering, but rather the repartition of clusters is done over a set of rounds. The selection of CH is done via a distributed approach, and we've assumed that each node has enough storage space in its buffer to carry the list of information required for this method's implementation. In the EECS protocol, numerous sets of rounds are examined based on preceding rounds, with each set having an equal number of rounds Rt. The first series of rounds of each R_t are referred to as commander round Rc. The number of rounds Rc in one complete set of rounds should be sufficient to allow each cluster node to become a CH at least once. Each node creates a list of crucial information during the setup phase of each commander set's round. This set of data is stored in the nodes for the following rounds and is used to construct a cluster in subsequent rounds.

For each round, each node holds the following list of data.

- Round ID and TDMA of its concurrent nodes if CH is selected.

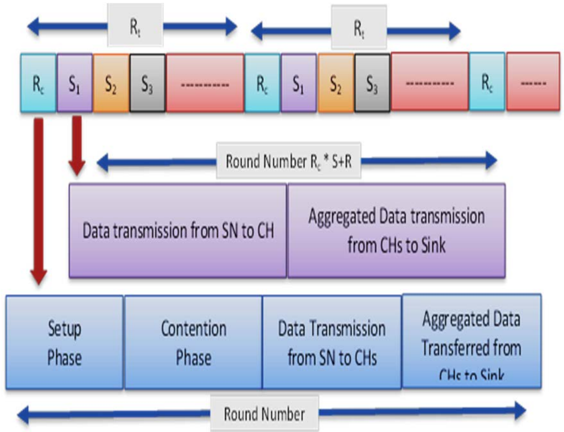

FIGURE 6. Detail of proposed circular spinning method.

- If not designated as a CH, the ID of the CH with which it is contemporaneous, as well as the TDMA slot number for data transfer

Every node in the commander set around Rc saves this list of data. And, based on the previously mentioned information, the cluster setup is repeated for the next 100 cycles to establish a dynamic cluster. Extra energy consumed just in the first set of 100 commander rounds Rc of the cluster setup stage has been saved in the next set of 100 rounds by using this approach. According to the maintenance list, each node knows its current status in advance of the next round; therefore no CH advertisement or node association is broadcast in the network. As a result, after completing the initial commander round, set Rc and all nodes will self-start and send acquired data without the need to wait for the next commander round.

As shown in Figure 6 Rt is the total number of sets of rounds that rotates. R_t is greater than R_c and integral multiple of Rc, s, is the number of sets in R_t.

$$S_{set} = \frac{R_t}{R_c} \tag{22}$$

And for round number r of Sset

$$R_c \times s + r \tag{23}$$

where $s = 1, 2, 3, \ldots\ldots\ldots S_{set}$

For example for 100 total number of rounds (Rt) if the commander round Rc is 10 then the number of sets in the total rounds is 10. The schedule of commander rounds will be saved in every node. And after these 10 commander rounds schedule will be repeated for 10 sets without repeating the cluster setup phase in each round.

A. PREVENTIVE MEASURES OF EECS PROTOCOL

In the mechanism described above, after a certain number of rounds, a node may fail, but the linked node will continue to send data in succeeding rounds. Particularly, nodes should be able to determine the fitness of their CH after some time. As a result, after a specific amount of time, a broadcast

TABLE 4. Variables and detail of variable used in Pseudo code of EECS.

Variable	Detail of variables
Rnd	Total number of rounds
R_c	Commander or first set of round
R_t	Total number of rounds after which commander round R_c initiated
N	Total number of nodes
S_{set}	Total set of rounds repeated after R_c
Record_i_Cluster Head	Enumeration of cluster head
Record_i_nodes	Enumeration of nodes

phase is required to determine each node's fitness. This period is represented by Rt in terms of the number of rounds in our EECS, and the entire network is rescheduled before the energy of one or more nodes begins to deplete abnormally. As a result, after each Rt round, a new set of Rc is created, and a fresh list of information is saved in each node. The setting of the whole list of rounds of the algorithm is shown in figure 6 and the procedure is given in pseudocode 1. Variable and notation used in proposed EECS algorithm shown in Table 4.

In EECS the identified extra energy is consumed only in few numbers of rounds instead of all rounds and reduces total network energy consumption of the network. It can be understand from the following scenario:

Assume there are 1000 data gathering rounds in a network and in each round, r units of energy are used solely for cluster setup. Then, out of total energy, 1000 round Extra Energy is consumed. Assume that each node saves its cluster setup sequence in memory during the first 100 rounds out of 1000. For each round, the cluster setup sequence, which requires only a small amount of memory, contains the following information.

a. Status of each node either CH or an associated node

b. In case of CH then knows it TDMA schedule

c. In case of associated node knows it CH to which it associated and its TDMA schedule slot.

In the next 100 rounds, each node with the same sequence can use this cluster setup information to create dynamic clusters. As a result, the Extra Energy used in the first 100 rounds will not be used in the subsequent 100 rounds. This information can then be used for each subsequent set of 100 rounds. The number of rounds in the first set, which we refer to as Rc, can be changed. After certain sets of 100 rounds, the Cluster setup sequence data entries can be refreshed. The main benefit of the EECS method is that it maintains the main feature of a Dynamic Cluster-based network: it distributes energy consumption among all nodes equally and fairly and at the same time it also reduces the overall consumption of network energy.

The result of EECS is shown in section V

V. SIMULATION RESULT AND PERFORMANCE ANALYSIS OF EECS PROTOCOL

In this part, some existing underwater clustering routing protocols were chosen as references to verify the proposed

Pseudo Code: Pseudo code of EECS

Initialize:

R_t the total number of rounds(r)
S total number of set in R_t and set S = 0
R_c commander round
N the number of nodes
Cluster head count = 0
E_tTotal Energy consumption of network

Input:

Total round R_t (Rnd)
Commander round R_c

Steps (directions)

```
For each round (r) 1 to Rnd
        For each round (r) 1 to S_set
Where: S_set = R_t/R_c
If r< R_c
        Enter into Cluster Setup Phase
        For Each Node i (i to N)
                If node –i selected as Cluster head
                Set Node i_ type =" Cluster head"
                Construct record i_Cluster head (r) for
                this round
            else
                Construct record i_node(r) for this round
                end if
Set a cluster head_count (r) = number of cluster heads in this
rounds
        end for
end if
If r > Rc
Set cluster head _count (r ) = cluster head_count(r-R_c)
        If (r/(R_c*(S+1))) > 1
        S = S+1
        end if
end if
If (r > R_c & r <= R_c* (S+1)
        For node i (1 to n)
                If Node i-type = "cluster head"
        Assign values from Record i_Cluster head (r- R_c)
        else
        Assign value from Record i_ nodes (r-R_c)
                End if
        End for
  End if
If r <= R_c
Compute energy consumption for cluster setup and data transmission to the sink from equations 19 and 20 and Compute total energy consumption from equation 21
Else
Compute energy consumption for data collection and transmission to the sink from equation 20 and compute total energy consumption.
End if
End for
```

Output:

Total Energy consumption of network

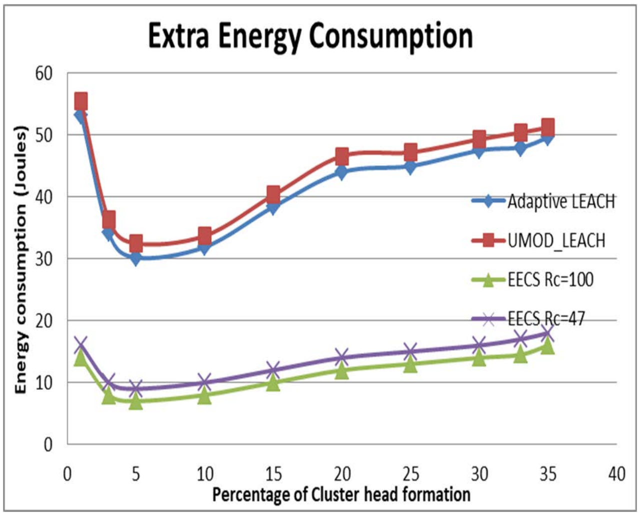

FIGURE 7. Extra energy consumption in different protocols.

EECSP: Modified LEACH [3], UMOD-LEACH [13]. The experiments were carried out using MATLAB. For evaluating the performance of the proposed algorithm we use the following parameters:

- Extra energy consumption
- Energy consumption of network
- Energy consumption per round
- Life of the network

A. EXTRA ENERGY CONSUMPTION

As we discussed above, to conserved energy of networks we minimize transmission of networks and we accentuate, the energy consumed during the setup of the clustering algorithm is considered as Extra Energy. This energy consumption is not part of the communication and it's an energy consumption used for cluster setup and election of CH. Figure 7. Show that, in Adaptive LEACH and U_MOD LEACH lowest extra energy is 30% and 33% of network energy consumption at 5% cluster head formation. As the number of cluster head formations increased it augmented. To overcome this extra energy consumption we minimized re-clustering and proposed an EECS mechanism. As shown in Table 5 and Figure 7 minimum extra energy consumption of Adaptive LEACH and UMOD LEACH are 30.2 and 32.5. Our proposed EECS has minimized the CH selection phase and reduced these extra energy consumption 7 joules to 9 joules for the 5 percent of CH formation at commander round Rc is 47 and 100 respectively. At commander rounder Rc = 47, the reduction of extra energy consumption is 20% from LEACH and 23% from U_MOD LEACH. At commander round, Rc = 100 rounds reduction in extra energy consumption is 23% from LEACH and 26% from U_MOD LEACH. This conservation of extra energy consumption prolongs the life of the networks.

B. ENERGY CONSUMPTION OF THE NETWORK

In Figure 8, analysis of the performance of proposed EECS by varying the value of commander rounds R_c i.e. 100 and 47 for R_t is 1000 rounds. Estimate energy consumption along with the varying setup of cluster head formation. It is observed from Table 6 and Figure 8 that at 5% Cluster head formation minimum network energy is 245 joules for Rc is equal to 47, while Adaptive LEACH and UMOD_LEACH consume more energy as compared to EECS. The proposed adaptive EECS conserved 21.5% and 28.4% of network energy from Adaptive LEACH and UMOD-LEACH respectively. In comparison with the adaptive LEACH, UMOD_LEACH outperformed LEACH, on average by more than 30% when the amount of transmitted data is more than 70% of the maximum while looking the same with small transmitted data. Table 6 shows only a prominent state of energy consumption and show that after 5% cluster formation network energy increases with the increasing value of cluster head formation. Due to localization UMOD_LEACH consumes more energy than adaptive LEACH. It is shown in the Figure 8 that the proposed EECS protocol at the setting of 45 of commander round consumes approximately 21.5% and 28.4% less energy than Adaptive LEACH and UMOD LEACH and extends life of networks.

From Figure 8, the result obtained from extensive simulation of UWSNs model, with the implementation of EECS mechanism for the different number of cluster heads in the network of 1000 nodes. And demonstrate that our algorithm works much better than Modified LEACH and UMOD-LEACH. We analyze our algorithm with a different set of Rc and S for 1000 rounds. The minimum value of energy

TABLE 5. Comparison of extra energy consumption.

Percentage of CH formation	Adaptive LEACH	UMOD_ LEACH	EECS (Rc=100, Sset=550)	EECS (Rc=47, Sset= 470
5	30.2	32.5	7	9

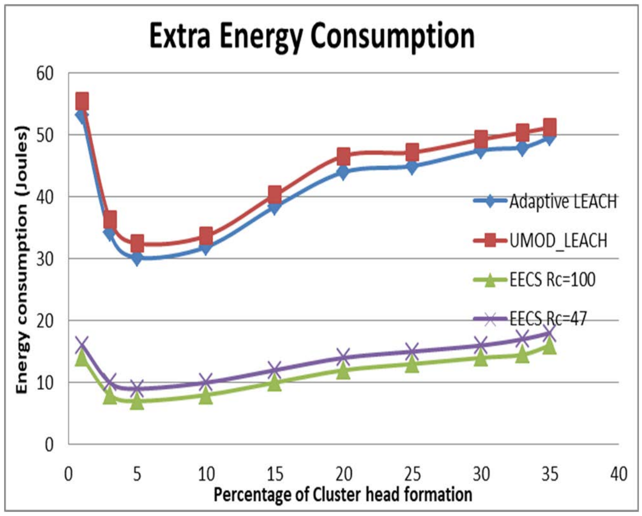

FIGURE 8. Network energy consumption in joules in 1000 rounds for LEACH, UMOD_LEACH, and EESC at different values of Rc and S.

TABLE 6. Comparison of energy consumption of networks.

% of CH formation	Adaptive LEACH	UMOD_ LEACH	EECS (Rc=100, S_{set}=550)	EECS (Rc=74, S_{set}=370)	EECS (Rc=47, S_{set}= 470)
3	380.4	390.4	270	259	245
5	312.5	322	218	194	180
10	317.8	330	225	200	187

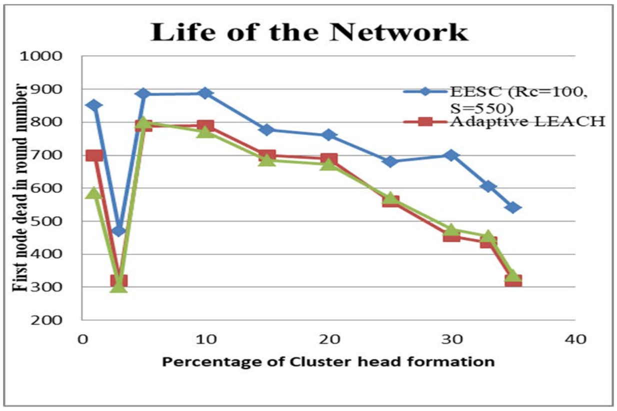

FIGURE 9. Life of the networks.

consumption is at 5% of cluster formation. Further for the analysis, we take three different parameters of Rc and S and a nominal difference in total network energy consumption found with varying size of Sset as in the first case S_{set} = 5 while in 2nd 3rd case S_{set} = 5 and 10.

C. NETWORK LIFETIME

If the network life is assumed as the time at which the first node of the network dies then the maximum lifetime is attained at 5% of cluster head formation. As shown in Figure 9, and Table 7 our proposed EECS outperforms LEACH and UMOD_LEACH and extends the life of the network. Table 7 represents only conspicuous state of network life. The maximum lifetime attained at 5% to 10% of cluster head formation and most appropriate to UW cluster base mechanism.

D. NETWORK ENERGY CONSUMPTION PER ROUND

Considering the optimum percentage of cluster head formation and assigning 5 joules of initial energy to each node, the total network energy consumed per round is shown in Figure 10. At 47 rounds setting of commander round, it can be observed from Table 8 that approximately 21.5% less network energy consumed at 1000 rounds from LEACH and 28.6% less from UMOD_LEACH. For analysis of our EECS algorithm, we take two different parameters of R_c and S_{set} and demonstrate that how can our proposed scheme can influence and improve the dynamic round base clustering scheme. Table 8 represent specifically the most prominent rounds of network energy consumption.

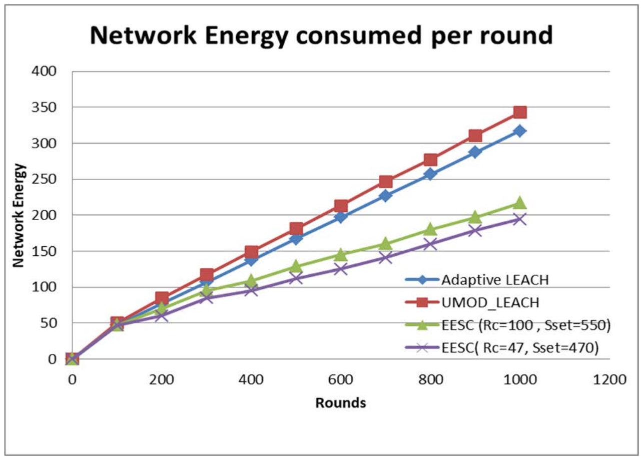

FIGURE 10. Comparison of network energy consumption per rounds of EECS protocol for different values of Rt and Sset with a different protocol.

TABLE 7. Comparison of life of network.

Percentage of CH formation	Adaptive LEACH	UMOD_ LEACH	EECS (Rc=100, Sset=550)
3	320	300	470
5	788	800	885
10	789	770	887
15	700	685	777

TABLE 8. Comparison of networks energy consumption per rounds.

Rounds	Adaptive LEACH	UMOD_ LEACH	EECS (Rc=100, Sset=550)	EECS (Rc=47, Sset= 470)
100	47	50	47	47
200	77	85	70	60
500	167	181	129	112

VI. EVALUATION OF EECS PROTOCOL

In section IV it is discussed that EECS protocol reduces the amount of energy consumed in the cluster setup phases. Basically EECS mechanism reduces the repetition of broadcast packets used for the purpose of cluster formations. In EECS mechanism multiple set of rounds are considered in prior where each set contain equal amount of commander set of rounds R_c. In a commander set of round a list of information is constructed in each corresponding node's memory during their setup phase. As shown in pesocode1 each node maintains the list of subsequent sets of rounds and utilized it to form cluster in subsequent rounds. There for it is assuming that each node has enough storage space to hold this information.

The information in the list that each node needs to save is given in Table 9. Let's the data unit in bytes (Bytes) is assume to hold one item, each from the list shown in Table 9. The amount of data storage (D_s) is the highest for holding TDMA schedules of associated nodes which has to be maintained at the CHs of each round.

TABLE 9. Total data storage required at each node in each R_c.

Item to store per Commander Round	Data unit (Bytes)
Round ID in which selected as CH	1
TDMA of associated node in case selected as CH	N_i
ID of CH to which it is associated if not selected as CH	1
TDMA slots number to transmit data	1

Suppose the length of the commander round R_c is such that each node become a CH at least one time in it, then the average amount of data storage (D_s) required at each node is:

$$D_s = R_c * B(\mathrm{N}_i + 3) \tag{24}$$

The space complexity of EECS in big O notation is O (n). The time complexity of EECS is depends on input size of R_t and R_c and it is $O(n^2)$.

VII. CONCLUSION AND FUTURE WORK

Energy efficiency is the major concern of the researchers because in the underwater environment it is very difficult to replace batteries of the network. In this paper, to reduce energy consumption and extend the life of the network an effective dynamic cluster-based mechanism has been proposed by reducing the advertisement phase of clustering. It is observed a significant amount of energy is consumed in the cluster setup as compared to receiving and listening and it is the main contributor of energy consumption, based on this observation we investigate to reduce transmission and limit the advertisement phase of clustering.

Our proposed EECS mechanism unlike previous work is to maintain node synchronization not avoid completely re-clustering. Focuses on cluster setup we present the novel idea of commander round which can preserve the history of CH selection and follow it for further rounds and conserve a substantial amount of energy. We analyze EECS through extensive simulation and performance parameters are extra energy consumption, total energy consumption, energy consumption per round, and life of the network. It is found that the proposed scheme conserved 21.5 to 28.6 percent of network energy and prolongs the life of the network. In the future, we have a plan to extend this work for multi-hop cluster based UWSNs.

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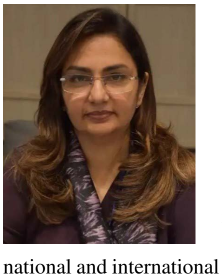

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