Energy Efficient Scalable Routing Protocol (EESRP) for Underwater Acoustic Sensor Networks Using Random Linear Network Coding

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Abstract

In Underwater Acoustic Sensor Networks (UWASN), sensor nodes are used for collecting information from seabed, monitoring pollution, and for various surveillance applications. Underwater sensor nodes are prone to failures because of fouling and corrosion. In Sensor Network (WSN) each sensor node consists of a battery, transmitter, receiver and a processor. Replacing or recharging the battery is not possible every time. So energy balancing is a critical issue during communication. In this paper, Inter-Intra Cluster Energy Balanced Routing (EESRP) protocol is proposed for UWASN to overcome latency and other interference as well as make the entire network is energy balanced. The proposed energy balanced routing protocol is required for communicating the sensed data between the nodes. To reduce the energy extraction during communication between the nodes and thereby improving the network lifetime can be obtained by applying network coding technique in inter and intra cluster. The simulation results show that the proposed EESR protocol can reduce the number of node failures, finding usage of energy of each node and effectively prolong the network lifetime. Also this protocol has better performance on energy-efficiency, end-to-end delay and throughput compared to other existing protocols

Keywords: *Inter-Intra Cluster, Energy Efficiency, Network Coding, Underwater Acoustic Sensor Networks*

1. Introduction

In Marine research one of the challenging issue is communicating information from seabed to control room or base station. Wireless underwater acoustic networking is the enabling technology for these applications. In UWASNs to perform collaborative monitoring tasks in given area number of sensor nodes and vehicles are deployed randomly. To obtain this objective, sensors and vehicles are self-organized in an autonomous network which can adapt to the characteristics of the ocean environment given in [1]. In Underwater Networks the sensor nodes and vehicles are having a capability of self-configuration. That is each node in the networks able to coordinate themselves and transferring their information to the neighboring nodes by sending their location, energy level, buffer size and sensed data. Also these information s are transferred to the shore station. Currently many investigators are focused on developing solutions for terrestrial wireless ad hoc and sensor networks. The existing protocols does not support the underwater scenario since the underwater acoustic networks has unique features like limited bandwidth and variable delays. These problems are addressed in [2].

In order to design an effective communication technique, new protocols and electronic devices had to be devised since it is now always possible to bring the strong experience developed in the field of terrestrial network design to that of underwater ones. In fact, the conventional radio frequency (RF) communication techniques perform inefficiently in underwater scenarios due to their quick attenuation and signal absorption. The presence of shadow zones and the multipath effect also causes the deterioration of the signal as the speed of the acoustic signal varies with the depth and salinity of the water. In this context, the design of routing protocol is one of the major challenge. Industrial and

ISSN: 2233-7857 IJFGCN

academic researchers have devoted large efforts in this direction, and have proposed several solutions.

In UWASNs, routing protocols ensure efficient data transmission between the deployed sensor nodes, underwater vehicles, mobile sinks and the on-surface sinks. Moreover, the data collected by the on-surface sinks is transferred to the onshore base station usually through RF or satellite communication. There are multiple classifications of routing protocols on the basis of various routing ideologies. Some of them include Sender based, Receiver-based, Opportunistic, Depth-based, Localization-based and Localization-free routing algorithms. These classifications are useful in the selection of the routing protocols considering the targets of the desired underwater real time scenario.

2. Related Works

In this context, the design of routing algorithm is one of the major challenge. Industrial and academic researchers have devoted large efforts in this direction, and have proposed several solutions. In UWASNs, routing protocols ensure efficient data transmission between the deployed sensor nodes, underwater vehicles, mobile sinks and the on-surface sinks. Moreover, the data collected by the on-surface sinks is transferred to the onshore base station usually through RF or satellite communication. There are multiple classifications of routing protocols on the basis of various routing ideologies.

The advancement of underwater communication is necessary for the scientific research community as oceans cover the 70 percent of the Earth’s surface [3]. Presence of ocean, seas, rivers, and lakes drives the major aspects of our daily life since it provides an effective medium for commerce and transport. According to [4], about 95 percent of the volume of the oceans is unexplored, thus leaving huge scope for improvement in research. In the past hundred years, most of the research related to underwater communication has been mainly done for military purposes during the world wars. There are three main ways of communication in underwater networks, which include acoustic, radio-frequency (RF) and optical communication. Due to its intrinsic characteristics, researchers prefer acoustic signal for the underwater communication as high-frequency electromagnetic waves confront extreme challenges caused by the aqueous environment. The optical fiber is also considered as a possible medium of communication, but it has its own constraints that include high scattering and large deployment cost due to the large coverage area requirement of underwater networks. Major discoveries developed in underwater research were made after the proposal of the passive sonar equation [5] which models the channel loss in the underwater communication.

In the past few decades, Underwater Communications have emerged as an important topic for aquatic research [6,7]. Acoustic communication [8] is widely adopted in underwater environments because of their two major properties. First, it faces low signal interference due to its longitudinal nature. Second, it can travel to a large distance due to its very low frequency while high frequency signal is absorbed in the water quickly. In the design of UWSNs, we have to account for some aspects that are crucial for their correct operation: UWSN nodes are powered by a battery whose replacement is particularly challenging. Therefore, one of the major aspects that we have to consider when we evaluate the performance of a protocol is its expected energy consumption and if it has the capability balancing the energy consumption among the nodes. Wave motion makes maintaining permanent routes in the underwater environment extremely difficult.

Therefore, reactive and proactive protocols such as the Ad hoc On-demand Distance Vector (AODV) [9] that search for a route and then maintain it for a long time are not applicable in general. The propagation speed of the acoustic signal in aqueous environment varies from 1450 to 1500 m/s which causes an increased transmission delay. It poses serious challenges for the delay sensitive applications, e.g., seismic monitoring and flood detection etc. The transmission power consumption of an acoustic signal in UWSNs is computed by the passive sonar equation presented in [10]. It calculates Signal-to-Noise Ratio (SNR) at the receiver based on some parameters among which the transmission power and the absorption loss play the major roles.

The authors suggest the utilization of underwater vehicles and effective deployment strategies of sensor nodes as a way to tackle the issues of high end-to-end delay and coverage hole. They discuss the challenges for specific underwater applications and propose the possible solutions in the context of 2D and 3D UWSN communication architectures. Furthermore, they classify the communication schemes, according to the OSI layered model and concentrate on the design of offline localization schemes to improve the performance of these proposed communication schemes. Authors in [14] explains the extension of lifetime of Underwater Acoustic Sensor Networks using Network Coding. This existing protocol is applicable only for regular and homogeneous networks. This protocol not suitable for random deployment of nodes.

Channel aware routing protocol was proposed in [11], this protocol provides the steady communication between the nodes on the basis of their packet delivery ratio to the base station. Furthermore, this protocol is used to find shadow zones based on the previous transmission and the overall network performance is improved. This protocol is mainly used in data-aware underwater applications. Authors in [12] propose a Segmented Data Transport Protocol (SDRT) which mainly pays block by block packet transmission. This protocol combines Forward Error Correction (FEC) and Automatic Repeat Request (ARQ) to formulate their hybrid approach and improve the channel utilization. The proposed scheme offers a replacement for the transport layer protocols designed for terrestrial networks (i.e., TCP and UDP) which are not suitable for the underwater environment. During the block-by-block transmission, they implement a transmission window idea to avoid the congestion.

Based on the depth threshold and energy level partition authors in [13] proposed an energy balanced algorithm for underwater communications. This algorithm executed based on two phases such as routing establishment and data transmission. Here authors proposed an analytical model based on transmission distance and to find the neighbors optimal distance. Based on these distances an underwater link is established. In data transmission phase based on energy level (EL) that is EL between the neighboring nodes in the links, the path between sources to destination gets dynamically changed. Based on Energy Balancing Algorithm, energy consumption of each node is reduced and thereby increasing lifetime of the network.

3. Proposed EESR Protocol

In UAWSN a set of nodes are deployed in an area to monitor the oceanographic conditions and record them. The recorded data are send it to a central location for further investigation and study. Each sensor node has major five units. It has communication unit which is equipped with chipcon transceiver and antenna, processing unit, with inbuilt micro-controller, an electronic circuit, sensing unit equipped with sensors and power unit. This power unit has battery source. Based on environmental condition each node in the network senses the changes in ocean and send this information to other nodes. Sensor nodes are great for deployment in hostile environment or very large geographical areas. In UWASN the assumption made is Battery life of node is directly proportional to Network lifetime. Another major problem is to make the algorithm energy efficient. In homogenous clustered routing algorithms, network is divided into clusters and each cluster has a cluster head who communicate with the base station on behalf of other nodes present in the cluster. Many algorithms improve the network life time by improving the selection of cluster head of the cluster. Improvements like applying ant colony optimization, differential evolution, selection based on residual energy of nodes. Many solutions were proposed like ordering the cluster head role in fixed pattern and increase the network lifetime. But each algorithm or protocol has some drawbacks.

Mainly this paper focus on study of inter-intra energy efficient algorithm of underwater acoustic sensor network i.e. Depth Based Routing (DBR), Probability Depth Based Routing Protocol (PDBR) and findings the gaps among them. The main gap is selection of Cluster Head and balancing of energy for every round has been shortlisted to be addressed in the presented work.

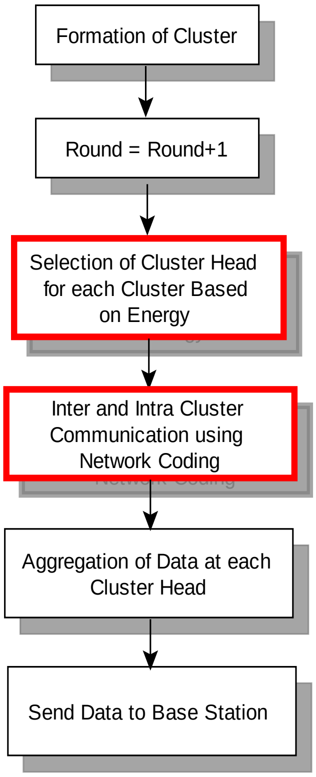


Figure 1 Flow Diagram for EESR Protocol

3.1. Network Model

i. In this network scenario all the sensors are heterogeneous and sensor nodes are deployed in known location but it is placed in randomly within transmission range.
ii. Each node in the network scenario is assumed that uses same power level for intra cluster formation and communication between the nodes. After each iteration, the CHs are formed based on the energy level. Then each cluster heads transfer the data to the sink or base station. Cluster heads energy level is reduced based on the distance between CHs and the Sink node.
iii. Sensor nodes are used to monitor various physical parameters such as temperature, ocean current, pressure and salinity.
iv. The unique feature of underwater sensor networks is that each node has unique Identification Number (ID) so that each node knows the neighbors location.

ISSN: 2233-7857 IJFGCN

v. Based on the energy level nodes are partitioned and forms the tiers or layers. Each partition has one cluster head and members. Cluster heads collect the information or data from members and send the collected data to the base station.
vi. Entire network uses the OFDMA scheme. That is inter and intra cluster uses the OFDMA scheme for communication and use different frequency. Members in each cluster and intra cluster communication is carried out based on LNC algorithm and OFDMA scheme to send the data to intermediate nodes.

3.2. Mechanism of EESRP

The mechanism of EESRP is based on repetitions referring to DBR. Each round or iteration has two segments. First segment is initialization phase and second segment is data transfer. Cluster head selection is done in initialization phase. Each cluster head forms a cluster by choosing its members based on energy and buffer level.

After formation of cluster heads and cluster members data transfer phase has been executed. In data transfer phase each member in the cluster sense the data and transfer to concern cluster heads. This type of communication is said to be intra cluster communication or intra cluster data transfer. Each cluster head transfer the aggregated information to the base station or Sink node. This type of communication is said to be inter cluster communication.

In this proposed EESRP there are i nodes ranges from $1 \le i \le 10$ and broadcast the information as each node wants to flooding its j information to node which ranges from $1 \le j \le 10, i \ne j$, that is all the nodes in the cluster transmit the information to all other nodes in the same cluster. Each cluster has cluster head and members. Assume that each node N_i can transmit data to its cluster head with in the transmission range. The distance between cluster head and member is only one hop.

Let E_{total} be the total energy consumed by each node which present in network scenario. In UWASN the total energy consumption of a node is mainly depends energy used by a node during transmit, receive, sensing and computation. Let us consider there are N number of member nodes in the cluster. Total energy used by a nodes can be written as,

$$E_{total} = E_{tx} + E_{rx} + E_S + E_C \quad (1)$$

3.3. Channel Model for Underwater Communication

Attenuation of distance d for acoustic channel in underwater environment can be expressed as,

$$A(d) = d^{\lambda} \alpha^{d} \quad (2)$$

Where λ is the energy spreading factor (1.5 for practical)
$\alpha(f)$ - Absorption Coefficient

Based on frequency the absorption coefficient can be calculated based on Throp's expression given in [14], and can be written as,

$$10\log(\alpha(f) = 0.11\frac{f^2}{1+f^2} + 44\frac{f^2}{4100+f} + 2.75\times10^{-4} f^2 + 0.003 \quad (3)$$

The absorption coefficient is measured in terms of decibels per kilometer for various frequency in KHz.

3.4. Transceiver Model

In the proposed protocol we used the energy model for Mica 2 for simulation. Here transceiver electronic circuitry radio dissipates $E_{elec} = 50nJ/bit$ and energy consumed by an amplifier which present in transmitter and receiver is $\varepsilon_{amp} = 100pJ/bit/m^2$ as shown in Figure 2. Here the data packet size is, $k = 512bits$

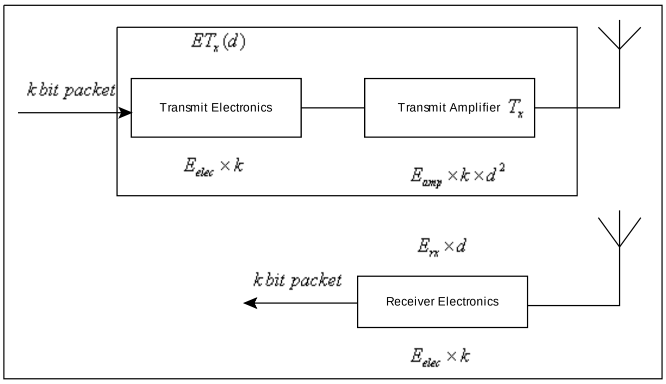


Figure 2 Transceiver Model of Mica 2 Mote

Energy Consumption during data transfer between the nodes over a distance d in underwater channel is given by,

$$E(d) = E_t(d) + E_r(d) \tag{3}$$

$$E_t(d) = l\left(E_{elec} + \varepsilon_{amp}\right) + P_t \times \frac{l}{\alpha \times \omega(d)} \tag{4}$$

$$E_r(d) = l\left(E_{elec} + E_{DA}\right) + P_r \times \frac{l}{\alpha \times \omega(d)} \tag{5}$$

From equations (4) and (5) we know that P_t and P_r infers that transmit and receive power respectively, l is the size of the packet, $\omega(d)$ is the available bandwidth and α represents bandwidth efficiency of the modulation and can be measured in terms of bits per second(bps) per hertz, E_{elec} gives the unit energy consumption by the electronic circuits to process one bit of information or data, ε_{amp} is energy consumed by an amplifier, E_{DA} energy usage during data aggregation.

During initialization stage both the cluster head and member nodes in the cluster consumes energy. In homogeneous network all the sensor nodes have equal initial energy. In the initialization phase the sink node or base station sends the beacon signal to the nodes which present in the network scenario. All the nodes receive the signals and send the ACK signal to the sink node. Based on the signal strength cluster heads are formed then CHs send the signal to all other nodes. Then the associated nodes collect the signals from different cluster heads and based on the received signal strength each cluster heads choose its own members and forms the cluster. During this transmission each nodes consumes energy. Equation (6) infers that energy consumed by cluster heads and non-cluster heads.

$$E_k = N_{an}(E_{elc} + \eta(E_{elc}\ T_{bd}\ E_t \varepsilon_{amp})) + l\, \varepsilon_{amp}\, d_{snk}^2 \quad (6)$$

Where, N_{an} represents the number of sub nodes associated with cluster, η is denotes to the data collection ratio, T_{bd} denotes the duration of bit transferred from members to cluster head.

The consumption of energy by the non-cluster head nodes can be obtained from equation (7),

$$E_{ki} = lE_{elc} + T_{bd} P_t \varepsilon_{amp} \quad (7)$$

Total energy consumed by k clusters can be calculated from equation (6) and (7)

$$E_{total} = \sum_{1}^{N} E_k + \sum_{1}^{N} E_{ki} \quad (8)$$

The first term and second term of of the equation (8) represents the use of energy during receiving of message from k clusters and the energy consumed by the cluster head during transmit the acknowledgement messages respectively.

The optimal number of clusters can be obtained by equating the derivative of the total energy with respect to zero.

$$\frac{dE_{total}}{dk} = 0 \quad (9)$$

From equation (8) we obtained the total energy as given below,

$$E_{total} = [N_{an}(E_{elc} + \eta(E_{elc}\ T_{bd}\ E_t \varepsilon_{amp})) + l\, \varepsilon_{amp}\, d_{snk}^4] + lE_{elc} + T_{bd} P_t \varepsilon_{amp} \quad (10)$$

After equating $\frac{dE_{total}}{dk} = 0$, the optimal number of clusters can be obtained as follows

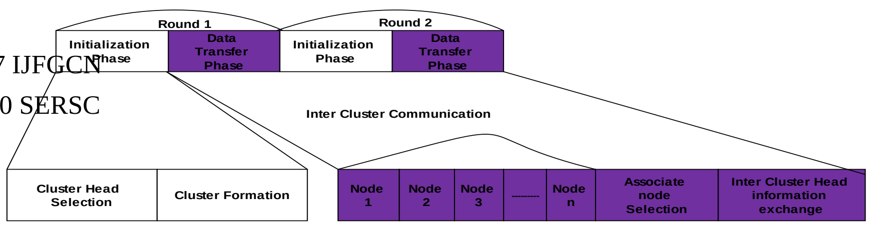
$$\frac{dE_{total}}{dk} = \frac{[N_{an}(E_{elc} + \eta(E_{elc}\ T_{bd}\ E_t \varepsilon_{amp})) + l\, \varepsilon_{amp}\, d_{snk}^4] + lE_{elc} + T_{bd} P_t \varepsilon_{amp}}{dk} = 0 \quad (11)$$

By simplifying the equation (11) we can obtain the optimum number of clusters. The finest number of clusters can be written as,

$$k_{opt} = \sqrt{\frac{N}{2\pi}} \sqrt{\varepsilon_{amp}}\, \frac{M}{d_{snk}^2} \quad (12)$$

3.5. Formation of Cluster

Figure 3 shows the time line diagram for inter and intra cluster formation of EESR protocol. Each and every round or iteration we have to calculated the received signal strength. As per the received signal strength, members in the cluster choose its own cluster head in the initialization phase.



ISSN: 2233-7857 IJFGCN

Figure 3 Clusters and Cluster Head Formation

3.6. Mechanism of Intra-Cluster Communication

During initialization phase, all the member nodes in the cluster except cluster head sense the environment condition and generate the l bits of data. This l bit of sensed data is send to the CH in different time slot in each iteration with transmission probability P. As per the OFDMA schedule each nodes in the cluster transmit and receive data. OFDMA scheduling reduce the energy consumption and with very less signal attenuation during the communication between the nodes by dividing long transmission link into short links. The sensed data of l bits from non-cluster heads are transmitted to the cluster head in each time slots. In existing protocol the election of cluster head and members are obtained by flooding pilot signal from base station to other nodes which is present in network scenario. But in EESR protocol non cluster heads select its cluster head based on received signal strength. Also in EESR protocol the end to end delay and energy consumption of each nodes can be reduced by applying linear network coding.

Based on the threshold value member nodes are selected by cluster head.

$$\gamma = \frac{E_{res}}{P_{txmn}} \qquad (13)$$

E_{res} gives the residual energy of each node and P_{txmn} is the power consumed by the member node when transmitting of 1 bit of data to the sink node. All the selected member nodes have the largest value of γ are assigned in a cluster.

In traditional protocol to reduce end to end delay authors used different techniques such as flooding, routing and relaying the pilot signal to the nodes. But in our proposed protocol we used linear network coding technique for intra cluster communication.

3.7. Intra and Inter Cluster Communication Using Network Coding

The broadcast nature of the wireless medium gives rise to more situations where network coding is beneficial. Figure shows the cluster model for intra cluster information exchange for random topology. In random deployment scenario each node in the routing path does not know the information about the cluster other than its neighbors. That is member nodes knows or it can communicate only its neighbors.

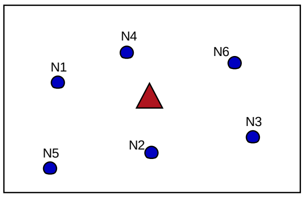


Figure 4 Intra-cluster Information Exchange

One of the challenging issue is to calculate exact transmission number in random topology in random method, but we can find the average number of transmission hop. The transmission hop can be obtained from $O(\sqrt{n})$. Optimum number of hop based on transmission can be written as,

$$O(T_{routing}) = O\left(\sqrt[n^2]{n}\right) \quad (14)$$

In intra cluster scenario each nodes uses network coding technique for broadcast the information to the cluster head. Based on this each cluster broadcast $\frac{n}{2}$ coded packets. Therefore number of retransmission and receiving of duplicate data or redundant data occurrence get reduced. Here each node uses $NC = n + \frac{n}{2} + \frac{3}{2}n$ which explains that each cluster head collect the information only from members and not responding the duplicate information. Also members in cluster sends its own sensed information directly to the cluster head without knowing any other information such as topology and geography, etc.

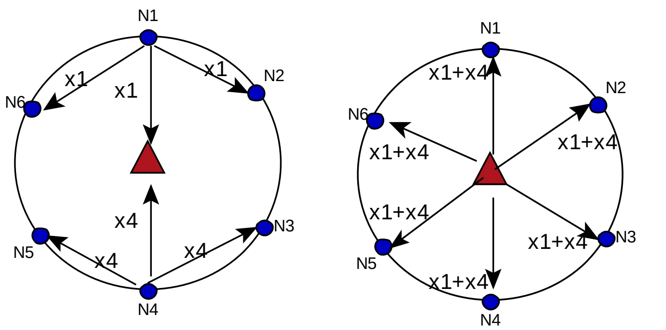


Figure 5 Intra Cluster Information Exchange using NC

Linear Network Coding mainly used for multiple sources. In order to provide reliable communication when any one of the link or nodes are failed to transfer data packets in inter and intra clusters each nodes in the cluster uses linear network coding technique. This linear Network Coding technique generate number of linear combinations of original data packets of length l bits. All the nodes in the cluster compute the coding matrix x_i at the source node. The dimension of coding matrix is $x_i \times n_i$ elements. Here each source node flood the $\frac{n}{2}$ data packets to the neighbors. Assume that the data flow from N_1 to N_6 .The data packet transmitted from N_1 to the sink node. The nodes neighbor to N_1 receive the duplicate information or data from its own transmission range.

4. Algorithm

To balance the energy and prolong the lifetime of the network, energy balanced clustering algorithm is designed. In this each cluster divides the nodes into k clusters based on equation (12). After finding the optimum number of cluster heads, member nodes in the cluster should know the location, energy and buffer level of the clusters heads. Let $x = (x_1, x_2, x_3, ... x_m .... x_n)$ be the set of the coordinates of the node, and the algorithm is as follows:

Step 1 From the set matrix x a node is chosen randomly as the number 1 cluster center c_1. After choosing a node from x, sink node calculates the distance between other nodes from cluster center c_1. Step 1 is repeated for all other nodes from x_1 to x_m. Based on the probability function $\frac{d^2(x_m.c_p)}{\sum_{j=1}^{n} d^2(x_j.c_p)}$ a new node x_m is chosen from cluster center c_p.

Where $d(x_m.c_p)$ is the Euclidean distance between x_m and c_p, and the p is the cluster number.

Step 2 Step 1 is repeated for all the k cluster heads.

Step 3 The distance between each node to each cluster center is calculated, and the node is computed to the nearest cluster head. It is denoted by $x_i \in c_p$, where c_p is the set of nodes in cluster p

Step 4The new cluster head in each cluster is denoted by $c_p = (1/|c_p|)\sum_{x_h \in c_p} x_h$, where $p \in \{1, 2, 3, ...k\}$

Step 5 Repeat steps 4 until reaching the number of setting iterations is completed

4.1. Quantitative Analysis

The radio communication and energy consumption described in Table 1. The attenuation of power is mainly depends on the distance between the transmitting and receiving node. For small distance and long distance communication the propagation loss modeled is inversely proportional to d^2 and d^4 respectively. Using the given radio and energy consumption models, the energy consumed for transmitting 1-bit of data for a shorter distance and longer distance d, the radio expends the energy level in given in equation (14) and (15),

$$E_{TS} = l \times E_{elc} + l \times \varepsilon_{fs} \times d^2 \tag{14}$$

$$E_{TL} = l \times E_{elc} + l\varepsilon_{mp} \times d^4 \tag{15}$$

Energy consumption during l-bit message is given by,

$$E_R = lE_{elec} + lE_{DA} \tag{16}$$

5. Simulation Setup and simulation results

The proposed protocol is simulated based on Table 1 simulation setup. EESR protocol is compared with existing Depth Based Routing (DBR) and Probabilistic Depth Based Routing (PDBR) protocol in terms of Total energy consumption, Number of Alive Nodes, Number of Dead Nodes, Packet Delivery Ratio and Throughput..

Table 1. Simulation Setup

Parameters	Value
Network Dimension	300x300 m^2
Initial energy for each sensor node	0.5J
Size of the Data Packets	1000 bits
Energy in idle state	50 nJ/bit

Aggregation energy	5 nJ/bit
Inter cluster Energy when d>=d_o	E_1=10pJ/bit/m^2
Inter cluster energy when d<=d_o	E_2=0.0013pJ/bit/m^2
Intra cluster energy when d>=d_1	$E_{11}=E_1/10$
Intra Cluster energy when d<=d_1	$E_{22}=E_2/10$
Location of BS	X=50; Y=50
Total number of nodes	100
Total number of rounds	1500

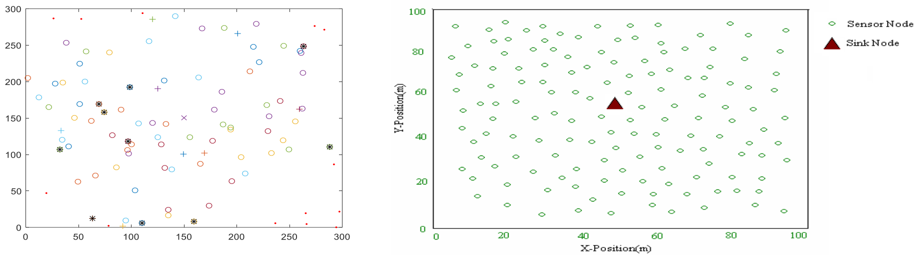


Figure 6 Simulation Scenario of Random Deployment of Nodes with Sink Node

6. Performance Analysis

Performance metrics of EESR protocol is analyzed based on number of iterations or rounds. Each iteration or round begins with initialization phase and followed by data transfer phase. Initialization phase includes sub phases such as cluster heads, member nodes selection and advertisement phase. In advertisement phase selection of cluster head by the member nodes and self-selection of cluster heads. During Data transfer phase schedule creation and data transmission.

6.1. Number of Alive Nodes

Figure 7 infers the energy efficiency of the EESR protocol. Energy efficiency of network is mainly depends on the number of alive nodes in the simulation scenario. In the proposed protocol of heterogeneous system is number of alive nodes is increased near to 80% than the DBR and 60% than PDBR heterogeneous system and energy consumption of the network is also decreased.

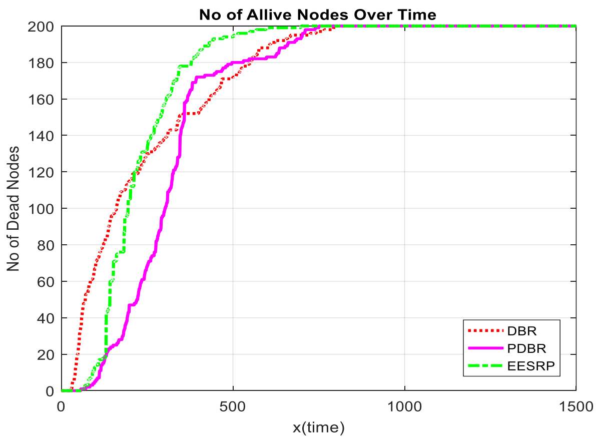


Figure 7 Number of Alive Nodes

6.2. Number of Dead Nodes

Figure 8 infers that the network lifetime of the proposed network scenario. The number of dead nodes is calculated for each round in order to find the network lifetime of the nodes. In the proposed protocol of heterogeneous system is number of alive nodes is increased near to 85% than the DBR and 70% than PDBR heterogeneous system and lifetime of the networks also increased.

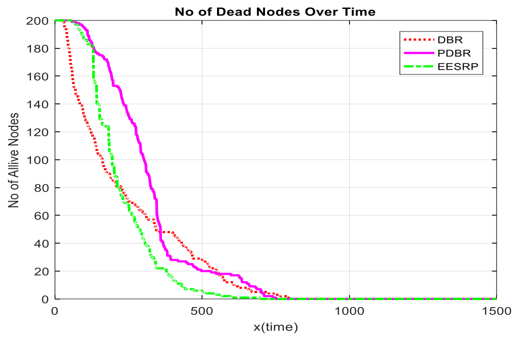


Figure 8 Number of Dead Nodes

6.3. Energy Consumption

Since the sensor nodes are equipped with battery energy consumption of sensor nodes plays vital role in underwater communication. Also network lifetime of the network is mainly depends on the battery lifetime. So in order to improve or enhance the lifetime of the network the energy consumed by the sensor nodes should be reduced. From Figure 9 we infers that the energy consumption of proposed EESR protocol is 46.22% and 86.7% of energy is saved than existing PDBR when the simulation time is 500 and 1500 sec respectively.

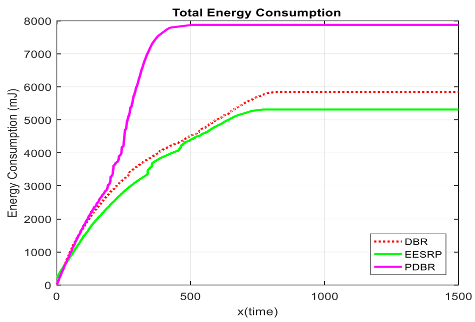


Figure 9 Total Energy Consumption

6.4. Throughput

Throughput

Figure 10 elucidates the throughput comparison of EESRP with DBR AND PDBR protocol. EESR protocol achieves a much higher throughput than the existing protocol. In the existing protocol more packet drop due to link or path failure. But in the proposed protocol we used linear network coding for reliable communication between the nodes. The average throughput of EESR protocol is 63% and 72% more than existing protocol when the simulation time varies from 100 to 500 sec.

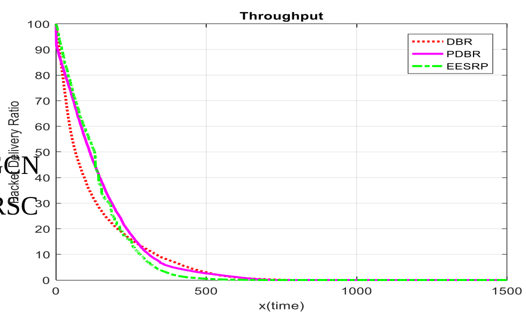


Figure 10 Throughput

6.5. Channel Utilization Efficiency

When the sensor nodes are deployed in underwater the acoustic channel capacity is mainly affected by temperature, propagation loss, depth and ambient noise of underwater environment. As the depth is increases the bandwidth increases but temperature decreases. However, bandwidth increases with increase in depth and temperature and decreases with increase in distance. Mainly there are three factor which decides the acoustic channel utilization. The packet size, forward error correction, and variation of packet train length is to overcome the delays and large bit error rates which is used to improve channel utilization.

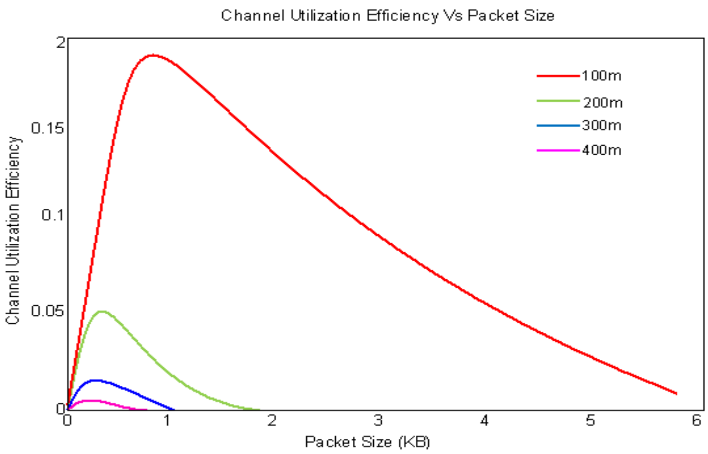


Figure 10 Underwater Channel Utilization Efficiency

7. Conclusion

In this paper we used analytical model for finding energy consumption of nodes during transmit and receiving of data. Also we developed mathematical model to calculate energy consumption during electing the cluster head and forming the cluster by choosing member nodes in each cluster. In EESR protocol we find optimum number of cluster heads. In this paper we made efforts to inspect routing protocols in underwater acoustic sensor network environment. After analyzing the results, we concluded that DBR protocol is not suitable for underwater networks due to its high rate of energy consumption. Energy consumption of sensor nodes is always a major concern in underwater networks. DBR is also not suitable because of its high routing overhead. PDBR are not suitable because it shows very low packet delivery ratio and throughput and routing overhead. EESRP has higher delivery ratio compared to existing protocols. The performance metrics of EESRP is more efficient compared to DBR and PDBR protocol at high traffic conditions.

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