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A ROUTING PROTOCOL FOR EFFICIENTLY MANAGING ENERGY IN UNDERWATER WIRELESS SENSOR NETWORKS WITH DEPTH CONTROL

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ABSTRACT

In Underwater wireless sensor network attracted massive attention from researchers. In underwater wireless sensor network, many sensor nodes are distributed at different depths in the sea. Due to its complex nature, updating their location or adding new devices is pretty challenging. Due to the constraints on energy storage of underwater wireless sensor network end devices and the complexity of repairing or recharging the device underwater, this is highly significant to strengthen the energy performance of underwater wireless sensor network. An imbalance in power usage can cause poor performance and a limited network lifetime. To overcome these issues, we propose a depth controlled with energy-balanced routing protocol, which will be able to adjust the depth of lower energy nodes and be able to swap the lower energy nodes with higher energy nodes to ensure consistent energy utilization. The proposed energy-efficient routing protocol is based on an Genetically updated Algorithm and data fusion technique. In the proposed energy-efficient routing protocol, an existing genetic algorithm is enhanced by adding an encoding strategy, a crossover procedure, and an improved mutation operation that helps determine the nodes. The pro- posed model also utilized an enhanced back propagation neural network for data fusion operation, which is based on multi-hop system and also operates a highly optimized momentum technique, which helps to choose only optimum energy nodes and avoid duplicate selections that help to improve the overall energy and further reduce the quantity of data transmission. In the remaining energy and directions of each participating node. In the simulation, the proposed model achieves 86.7% packet delivery ratio,keeping the energy usage at 12.6% and 10.5% packet loss ratio

Keywords: Routing protocol for efficiently managing energy ,depth control

are all terms used to describe underwater water wireless sensors.

I. INTRODUCTION

Energy efficient routing protocol is a promising technology that aims to solve the Energy usage issue in wsn. Under water wireless sensor networks (UWSNs) have emerged as focal points of both academic inquiry and industrial application, finding utility across a broad spectrum mitigation, secondary navigation, and energy exploration. The domain of UWSNs has recently experienced a surge in interest due to its advanced technologies tailored for underwater of monitoring, ocean and marine surveillance, well a specialized development for underwater sensing benchmarks. A UWSN comprisessensor nodes, base stations, and sink nodes, throughout the water environment, typically from surface seabed. These nodes collect data, which is transmitted to the sink nodes a sub sequently relaed tothe base station. Sensor nodes monitor various parameters of the from the shallow water

eco-system, such a temperature, and relay the gathereddata to sink nodes, either directly or through multiplehops. Previous studies have introduced various routing protocols for underwater data transmission via acoustic signals, but these methods often suffer from drawbacks such as high failure rates, have various types of the derived propagation delays, limited bandwidth, and of excessive energy usage In UWSN of the transmission, three primary routing methods are commonly employed.

The first method involves direct transmission, whereeach sensor node sends data directly to the sink.
However, this approach may lead to node depletion,particularly for nodes located far from the sink. The second method utilizes hop-by the transmission of data in a hop-by-hop manner involves each node forwarding information to the sink by selecting the nearest neighbor as its routing path. Consequently, there is a concentration of endpoints closer to the sinknodes, resulting in premature node depletion and a deterioration in both network performance and lifespan. Another routing protocol, termed "clustering-based routing," has garnered considerableattention from researchers. Under this approach, eachunderwater sensor node transmits its gathered data todesignated cluster heads (CHs), which then relay the ag
data to the base station. This method effectively reduces the necessity for direct transmission betweenindividual nodes, thereby mitigating bandwidth usageand enhancing overall network performance.
Although the architecture of UWSN closely resemblesthat of traditional wireless sensor networks (WSNs), itpossesses distinct characteristics such as prolonged end-to-end delay, limited bandwidth, and elevated biterror rates.
Implementing a routing strategy grounded in depthdata analysis has proven effective in minimizing both latency and energy expenditure. This approach dictates that when transmitting data, if a sender node identifies a neighboring node situated at a shallower depth and sharing overlapping lower-depth neighbors, the data is forwarded to thenode at the shallower depth. Another widely utilized techniqueis the genetic algorithm (GA), which mimics natural evolutionary processes to seek optimal solutions. GAs excel ataddressing optimization challenges and efficiently determiningthe most favorable multi-hop path between source and destination nodes. Typically, a random framework is employed to initialize the GA population, with a fitness function evaluating and selecting the most promising candidates for further refinement. Through iterative processes involving selection, mutation, and crossover, the population evolves, yielding progressively superior solutions. Nonetheless, several obstacles must be surmounted to optimize the performance of underwater wireless sensor networks (UWSNs). Common hurdles include battery longevity, deployment logistics, energy usage, and communication latency. UWSNs contend with various challenges inherent to dynamic underwater environments, such as increased energy usage, retransmissions,heightened power demands, and diminished accuracy. Present research efforts in UWSN energy routing predominantly revolve around enhancing energy efficiency. This study introduces an innovative depth-controlled, energy-balanced routing protocol (EEP) leveraging advanced GA techniques tailored specifically for UWSNs.

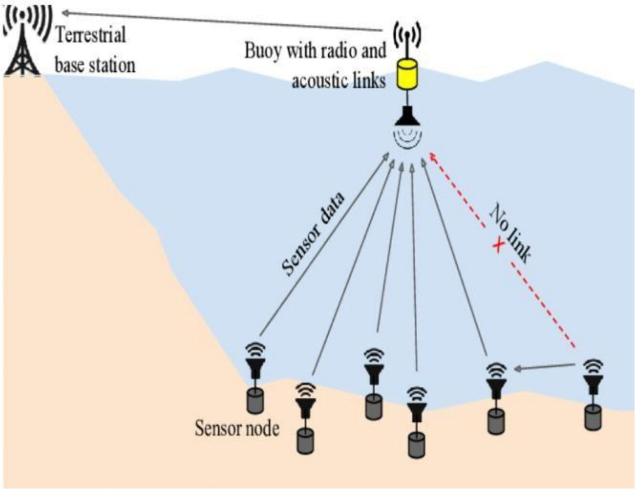

Figure 1. The architecture of UWSN.

This research introduces several pivotal contributions:

- Introducing the EEP methodology, aimed at prolongingnetwork lifespan through depth configuration. EEP prioritizes energy balance among clusters near and distant from sink nodes, by elevating higher-energy clusters and disrGUArding lower-energy points.

- Proposing a proactive approach to determine optimal node modification times, coupled with an efficient data transmission process to enhance network longevity.
- Employing an Genetically updated Algorithm (GUA) within the EEP framework to explore optimal multi-hop routing paths for Head Cluster Nodes(HCNs), employing a novel encoding strategy that encodes routing paths as chromosomes and nodesas genes.

- Enhancing the Back Propagation Neural Network (BPNN) for data fusion operations by integrating a highly optimized momentum technique, aimed at improving energy efficiency through reduced data duplication and transmission.

- Integrating two clustering routing protocols, GA, and data fusion strategies within the Depth-Controlledand Energy-Efficient Protocol, offering a unique approach tailored for UWSNs. Simulation results validate its effectiveness in extending network lifespan.

This research article is structured as follows: the introduction provides an overview, followed by a review of related works. The materials and methods section outlines the research approach, while results and discussions present findings and their implications. Finally, the conclusion and futureresearch section offers insights and directions for further investigation.
Underwater networking relies on water as the primarymedium of communication, presenting distinct challenges compared to terrestrial sensor networks. Traditional communication systems designed for land-based sensor networks are ineffective in deep underwater environments. Long-distance underwater communication often utilizes acoustic transmissions, while short-distance communication relies on transmitters. However, long-distance radio signal transmission requires massive antennas andsubstantial network throughput, leading to a shortenedlifespan for underwater wireless sensor networks (UWSNs). Additionally, acoustic transmission is characterized by longer delays compared to radio transmission, rendering many terrestrial wireless sensor methodologies unsuitable for UWSNs.Over thepast fifteen years, researchers have focused on investigating UWSNs, proposing various routing algorithms aimed at optimizing energy usage. Notableamong these are

clustering protocols, which have received significant attention. The Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm, for example, employsa probabilistic model to select Head Cluster Nodes(HCNs), though it does not consider the residual energy of endpoints. Other approaches, such as the underwater cluster-based method introduced by Gola and Gupta, utilize electromagnetism and Voronoi graphs to establish clusters and classify HCNs, resulting in considerableenergy savings and network improvement.

Additionally, researchers have explored adaptive routing mechanisms, such as the Cluster-Based Anycast Routing Protocol (CBAR), which utilizes route optimization and powercontrol methods to enhance network efficiency. Information fusion methods, like those employing Back Propagation NeuralNetworks (BPNNs), have also been proposed to improve energy efficiency by forwarding fusion data to nodes.Furthermore, techniques involving information gathering and fusion at portable sensor collection centers have been suggested to minimize energy usage and extend network lifespan.

In terms of localization routing, research has focused on methods like Vector-based Forwarding and Focused BeamRouting (FBR) to reduce power usage in UWSNs. These methods leverage sensor awareness of their positions and varying transmitting power requirements to optimize route selection. Depth-controlled routing techniques, such as Depth-Controlled Route (DCR) discovery, have also been proposed to adapt network topology and optimize routing paths, particularly in scenarios where conventional geospatial packet forwarding methods fail

Overall, the literature review highlights the diverse array of routing protocols and techniques developed for UWSNs, emphasizing the importance of addressing energy efficiency and network longevity in underwater environments

PROPOSED MODEL

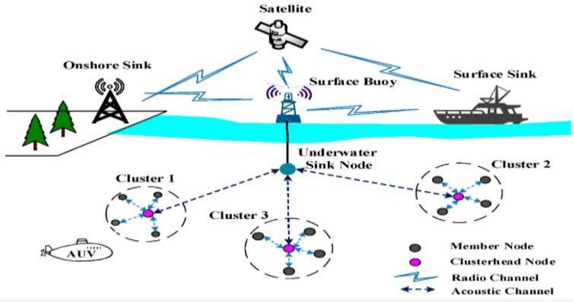

Figure 2. Proposed model.

The proposed Depth-Controlled and Energy-Efficient Routing Protocol (DCEER) also integrates Genetically updated Algorithm (GUA) and Data AggrGUAtion (DA) techniques tailored for UWSNs. Additionally, the protocol employs a Genetic Algorithm (GA) enhanced with specific encoding, crossover, and mutation procedures. Moreover, it leverages a Back Propagation Neural Network (BPNN) enhanced with an

optimized momentum technique to enhance energy efficiency by minimizing data redundancy and transmission. Furthermore, the EEP incorporates an Enhanced Cluster Head Node (OCHN) strategy to analyze the remaining energy and directions of each participating node.

The proposed model operates under several assumptions, including the presence of two types of participating nodes: UWS nodes, which are stationaryand further categorized into Head Cluster Nodes(HCNs) and Cluster Member Nodes (CMNs), and Sink Nodes positioned on the outer edge of the surveillance region. Additionally, it assumes the existence of only one Sink Node in the network responsible for containing the energy supply, while underwater sensor nodes possess limited energy without an energy supply mechanism. Normal underwater nodes are assumed to have uniform baseline energy and identification numbers, with localization techniques employed .

The proposed EEP method employs a Balanced Routing Protocol (BRP) and Aggrguation Ring Protocol (ARP) to manage data transmission

effectively. BRP divides each network node's limited

$$p=\sum_{i=0}^{n} R* \quad D*Max \quad *Ring \quad ^{2}$$

energy, particularly during multi-hop propagation where transmitters are typically closer to the sink node, necessitating higher energy for overall traffic communication. The design of the proposed model for UWSN, as illustrated in Figure 2, entails two phases: the Data Transmission Phase and the Designing of Proposed EEP Model for UWSN. The former phase establishes connections transformed based on energy levels during the latter phase, facilitating desired communication energy balancing and significantly extending the network'slifetime.Theenergy usage scheme of UWSNs differs from that of Wireless Sensor Networks (WSNs) due to

The unique attributes of underwater communication networks. Equation (1) illustrates the numerical solution, wherein each node in the network receives an energy threshold value represented by 'distance,' denoting the distance between sender and receiver nodes. Equation define 'fa' as the lowest power usageby a node to transmit data, with 'i' representing the frequency of a node.The primary objectives of these protocols are to mitigate energy usage in UWSNs. BRP, in particular, is designed as a protocol

The delineation of the sensing element's exposure region relies on boundary-based parameters, including the radial distance R of the private network, node density D, the width of each circular sector Ring the maximumlimit of hops Max, and the total number of participants P, as denoted by equation.The connectivity within the Underwater Wireless Sensor Network (UWSN) is subdivided into discretering areas Ar1 ... Arn, ranging from the interior to the exterior.The maximum count of these ring areas is determined by Ring/OT, where Ring represents the network radius and OT signifies the optimal connectivity path length threshold of sensing devices. Refer to Figure 2 for an illustration of the UWSN model architecture for underwatercommunication.Genetically updated Algorithm (GUA): This section elucidates the proposed GUA procedure utilized for identifying optimal multi-hop pathways among Head Cluster Nodes(HCNs) and Sink Nodes (SNs). The process involves a novel encoding method and distinct selection, crossover, and mutation phases. Optimizing the pathways enhances data transmission, reduces packet loss rates and energy usage, thereby extending the network's lifespan and enhancing its performance.

Problem Formulation: In formulating the Genetic Algorithm (GA) to discover optimal pathways, the network comprises (N^2 - 1) HCNs and One Sink Node. The Sink Node serves asthe ultimate destination, while a source node represents the CHN necessitating information transfer. Each CHN node is connected to a transmission node within the network. The connections between nodes i and j are represented by variablesY, Di, Eij, and Ki, denoting connection indication, connection energy cost, connection latency, and duration, respectively. The time taken for node i to transfer data packets is denoted by ti, and for node j to receive data packets is represented by tj. Dmax signifies the maximum delay permissible for the route. The presence of a connection between nodes i and j is indicated by a frequency value of Y equal to 5; otherwise, the combined value of Y is 0. The search for multi-hop routes is treated as a multi-objective optimization problem, aiming to identify the optimal route at minimal cost. This is formulated through the function (Fobj) as described below.

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$$\text{Fob}j = \sum_{i=1}^{n}\sum_{j=1}^{n} Y \ *Di$$

$$Di = ti * \text{MinPow} \ *Ki + Dr$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} Di * Y < D\ max$$

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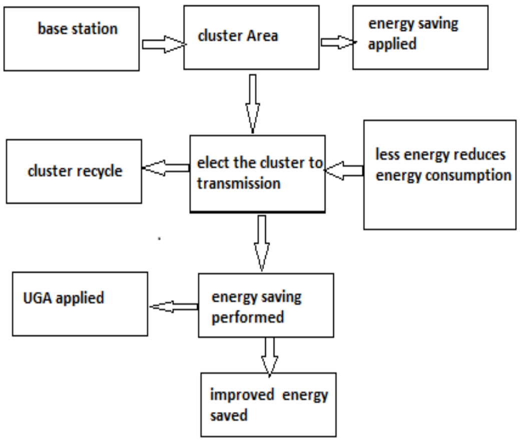


Figure 3. Proposed model work flow.

A. *The routing scheme in EEP*

The complete section elaborates on the enhanced GA,employed to explore optimal multi-hop pathways between sender and receiver nodes. It introduces a novel lossless encoding strategy and elaborates on theselection, crossover, and mutation operators.40

Optimal pathways, facilitated by these enhancements,can bolster transmission rates, minimize packet loss ratios, and decrease power usage, ultimately extending network longevity and improving overall performance. The following steps outline the implementation of the EGA method. Figure 4illustrates the operation of the proposed UWSN EEP model.Step 1: The central hub maintains oversight ofsensor devices within the UWSN and establishes cluster neighborhoods.

Step 2: Employing the proposed EEP approach, each cluster zone receives data from its constituentmembers, taking into

account the energy status of individual nodes during transmission. Additionally, a significant portion of portable sensor clusters is transitioned into standby mode, facilitating the rapid identification of nodes entering a low-power state. Initial energy levels are then monitored and allocated accordingly.

Step 3: Cluster endpoints are selected from each cluster zone using the Neighbor Discovery Methodology, enabling direct connectivity between nodes. This approach designates the appropriate cluster transmitter, promoting efficient energy utilization for data exchange.

Step 4: This process is reiterated with each cycle of cluster node formation, anticipating the inclusion ofnew digital endpoints or relocations within the network, thereby predicting the nodes accepted into the cluster zones.

Step 5: Sensor nodes are repositioned to aggregate informationacross the network utilizing GA following the composition of each cluster group and the appointment of new Cluster nodes within each cluster zone.

Step 6: The protocol assesses the energy levels within each cluster community and readjusts the cluster endpoints as needed, employing a straightforward approach. Subsequently,it anticipates the condition of the base station to preemptively address potential scenarios of battery depletion through the Energy Scheduling strategy embedded within the system.

Step 7: Within the UWSN, access points employ the Localization Method to track their positions, minimizing energy usage and prolonging thenetwork'slifespan.

RESULTS & ANALYSIS:

The energy usage issue stands at the forefront of challenges inUnderwater Wireless Sensor Networks (UWSNs). Overcoming this hurdle is imperative due to the constrained energy storage of UWS nodes and the intricacies involved in recharging or replacing batteries underwater. In this study, wepropose a Depth-Controlled and Energy-Balanced RoutingProtocol (EEP) for UWSN to address energy concerns effectively. This approach involves adjusting the depths of low-energy nodes and substituting them with higher-energy nodes to maintain uniform energy utilization throughout the UWSN.

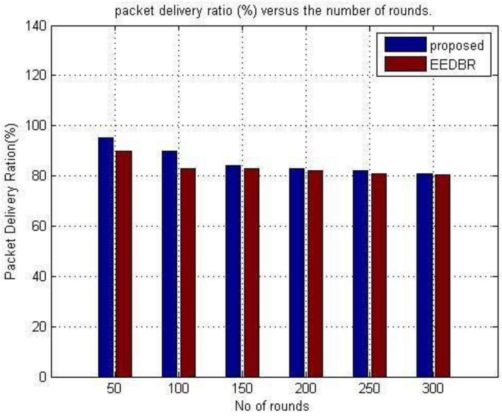
Energy usage:

The aggregate energy utilized by the network for transmission,reception, and data collection is referred to as energy usage. The outcomes of the simulation displayed in Figure 6 illustratethe energy usage patterns of the UWSN network across various routing protocols. Notably, the proposed EEP models exhibit superior levels of energy usage compared to existing DBR and EEDBR protocols.The simulation spanned from 10 to 100 rounds, with energy usage escalating as the number of rounds progressed. At round 20, the proposed EEP methods demonstrated a minimal energy utilization of 12.5%. Impressively, by round 80, the proposed EEP model showcaseda reduced energy usage of 20%, outperforming both existing DBR and EEDBR methods.

The packet delivery ratio (PDR):

The packet delivery ratio (PDR) represents the ratio of successfully transmitted packets to the total packets sent froma source to a destination within the network. Figure 7 illustrates the PDR of the UWSN network across variousrouting protocols. Notably, the proposed EEP method outperforms of to the existing EEDBR protocol.In the simulations, the proposed EEP method consistently achieves ahigher PDR compared to EEDBR across different scenarios. For instance, when considering 100 to 300 nodes in the network, the proposed EEP method exhibits a PDR that isA ROUTING PROTOCOL FOR EFFICIENTLY MANAGING ENERGY IN UNDERWATER WIRELESS SENSOR NETWORKS WITH DEPTH CONTROL

more than 7% higher than EEDBR. Furthermore, the EEP method demonstrates a PDR exceeding 90% across various instances, significantly surpassing the performance of both EEDBR and DBR protocols.



Packet loss ratio

Packet loss, or the failure of one or more transmitted packets to reach their intended destination, can occur within a network. When a new node joins the UWSN, it refrains from participating in the transmission process until it receives proper authorization. Figure 8 presents the simulation outcomes illustrating the packet loss ratio in the UWSN network across various routing protocols. This graphical representation depicts the relationship between packet loss percentage and network load, measured in packets per minute.The proposed EEP method consistently demonstrates superior performance across all instances, ranging from 10 to 90 packets per minute of network load. Specifically, for a network load of 10 packets per minute, the proposed EEP method exhibits a packet loss ratio of less than 10%, which represents the lowest level of packet losswithin the network. In comparison, the existing DBRmethod shows a packet loss ratio of 15.5%, while EEDBR exhibits a packet loss ratio of 10.5% under similar conditions. Overall, the proposed EEP method maintains a packet loss ratio across network loads ranging from 10 to 90 packets per minute.

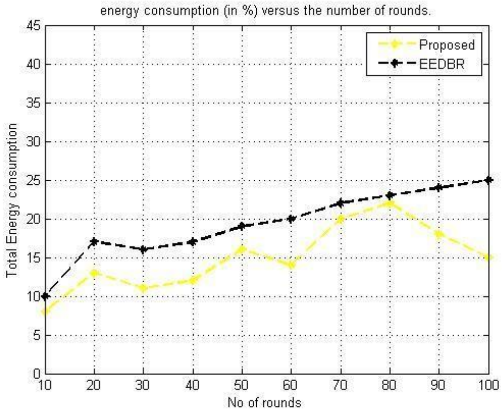


Fig-4: Energy Usage(in %) versus the number of roundsA crucial performance metric in UWSNs is thenetwork lifetime, which signifies the duration until the first sensor exhausts its powsupply. The frequencyof active nodes, their interconnections, and their spatial distribution collectively influence the average lifespan of the network. Simulation results, as depicted in Figure 7 and Figure 8, illustrate the network lifetime concerning the number of nodes for different radii, specifically 5 km and 10 km.Figures 9and 10 has been of the netwotk further highlight of thedecreasenetwork has lifetime as the network's radial distance and the nodes increase.

Notably, the proposed EEP method consistently exhibits a superiornetwork lifetime across both scenarios, encompassingradii of 5 km and 10 km with node counts ranging from 50 to 300.Figure

Fig-5:Graph Packet delivery (%) versus the number of rounds

Network time validity

11 presents a simulation graph depicting the network lifetime concerning various network radii. It demonstrates that as the network radius expands from 1000 to 8000 m, the network's lifespan diminishes accordingly. Remarkably, the proposed EEP method outperforms existing DBR and EEDBR methods across allinstances of the UWSN network, offering a superior network lifetime.Furthermore, illustrates the simulation resultsconcerning

the number of active nodes over rounds. The graph indicates adecline in active nodes

as the number of rounds increases from 100 to 1000. However,the proposed EEP method exhibits a higher number of active nodes compared to existing DBR and EEDBR of the a methods, signifying its effectiveness in prolonging the network's lifespan and sustaining node activity.well in scenarios where faster detection.

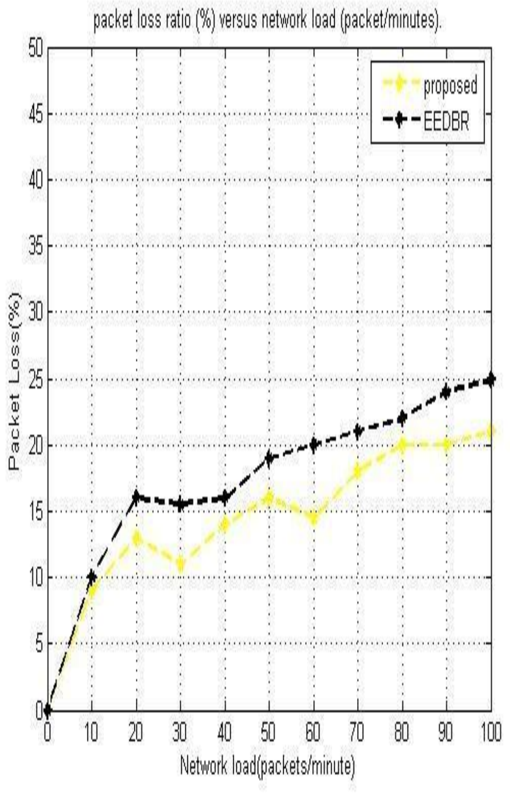


Fig-6: Graph Packet loss ratio(%) vesrus network load

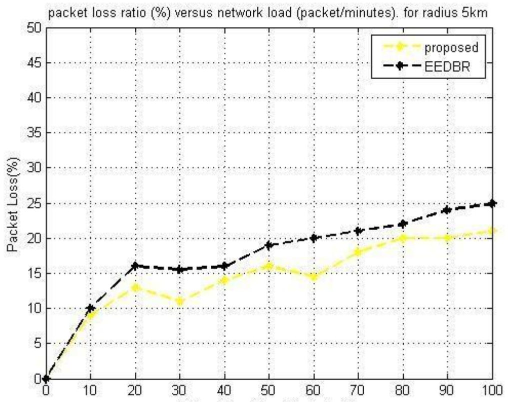
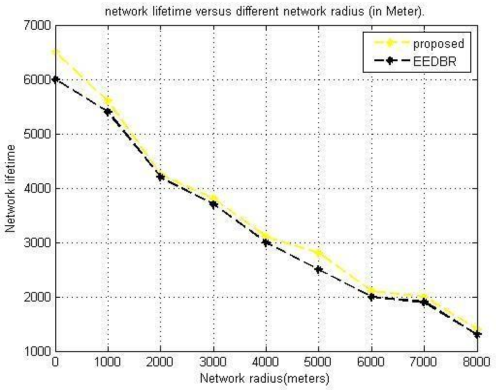


Fig-7: Graph Packet loss ratio (%) versus network loadfor radius 5km



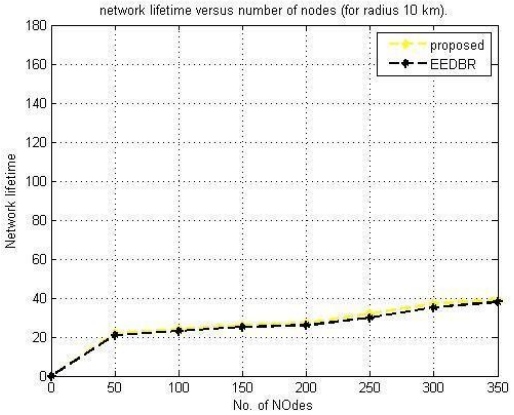


Fig-8: Network validity versus number of nodes(forradius 10 km)

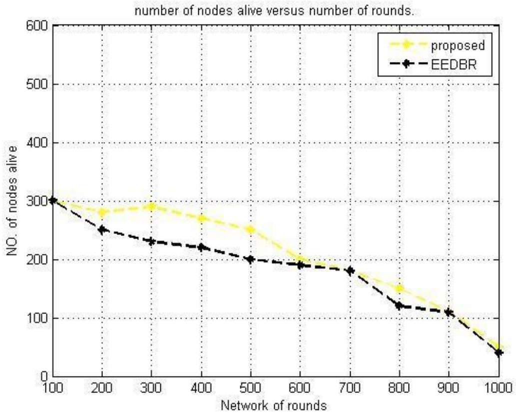


Fig-10: Number of nodes alive versus number of rounds

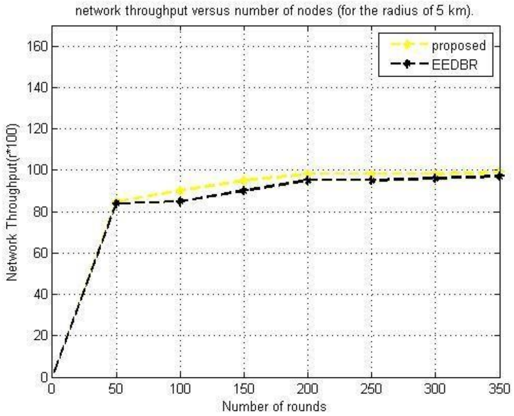
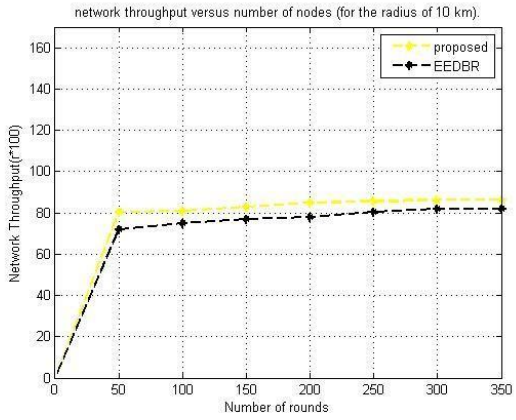


Fig-11: Network throughput versus number of nodes (for theradius of 5km

Throughput

Throughput refers to the total amount of relevant datathat a system can process within a defined timeframe.This performance metric is crucial for evaluating network efficiency and capacity. Simulation results for network throughput are presented for two distinct scenarios: one with a radius of 5 km and another with aradius of 10 km.

Figure 13 displays the network throughput results for scenario 1, where the radius is 5 km, while Figure 14 illustrates the corresponding results for scenario 2, with a radius of 10 km. Across both scenarios, it is evident that the network throughput tends to be higherwhen the number of nodes is lower. Additionally, the proposed EEP method consistently outperforms existing DBR and EEDBR methods in terms of throughput, demonstrating its effectiveness in enhancing data processing capabilities and overall network performance.



for energy-efficient routing solutions within UWSNs. This study introduces an innovative energy-efficient protocol (EEP) leveraging Evolutionary Game Algorithms (EGAs), integrating depth thresholds and energy delineates the underwater surveillance region, organizing IoT device sensors into distinct layers. Through MATLAB simulations, the efficacy of the proposed EEP approach is underscored, exhibiting superior performance metrics including enhanced throughput, reduced packet loss, elevated packet delivery ratios, prolonged network lifetime, and sustained node vitality when compared against existing DBR and EEDBR methods. Moving forward, future endeavors will explore the spatial progression

Fig-12: Graph throughput versus of nodes (for radius of10km)

Network transmission loss results :

The power at one stage in a UWSN transmission net- work is compared to the power at another location and the connection.[16,49–52] The lesser results for network transmission loss show better performance. Figure 15 shows the simulation results of network transmission

loss for various methods in UWSN. This graph shows that the network transmission loss increases once the network's radius increases. The proposed EEP method shows better performance (less transmission loss) for all the network instances from a radius of 1000 to 8000 m over existing DBR and EDBR methods.

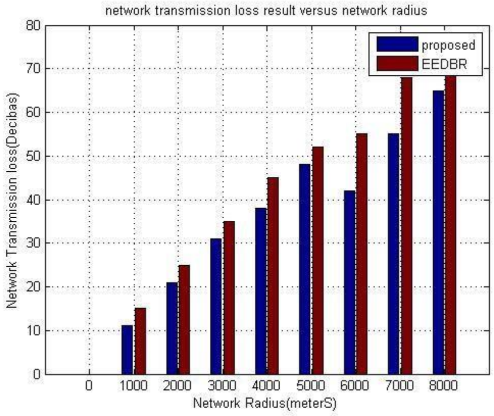


Fig-13: Network transmission loss results versus network radius

CONCLUSION AND FUTURE SCOPE

Sensor Networks (UWSN), the task of replacing batteries poses a considerablechallenge due to the expansive nature and inherent characteristics of water. Consequently, there is a persistent demand of energy ring sectors and the refinement of dynamic
depth thresholds. Additionally, efforts will be directedtowards mitigating the time complexity of the proposed EEP model, currently rated at O(n2), in contrast to existing DBR and EEDBR methods**.**

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