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An Energy Efficient Optimal Path Routing (EEOPR) for Void Avoidance in Underwater Acoustic Sensor Networks

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Abstract: UASN (Underwater Acoustic Sensor Network) has intrinsic impediments, since it is utilized and utilizes acoustic signs to impart in the sea-going world. Examples include long delays in propagation, limited bandwidth, high transmitting energy costs, very high attenuation in the signal, expensive implementation and battery replacement etc. The UASN routing schemes must therefore take account of these features to achieve balance energy, prevent void hole and boost network life. One of the significant issues in routing is the presence of void node. A void node is a node that does not have any forwarder node. The presence of void may cause the bundle conveyance in the steering time which prompts information misfortune. The gap during steering influences the network execution regarding proliferation delay, vitality utilization and network lifetime, and so forth. So, with the objective to remove the void node in the networks, this work presents an energy efficient optimal path routing for void avoidance in underwater acoustic sensor networks. This work uses the concept of gray wolf optimization algorithm to calculate the fitness function and that fitness function is used to select the best forwarder node in the networks. This work only considers the vertical directions which further reduces the end to end delay. The proposed work has been simulated on MATLAB and performances are evaluated in terms of broadcast copies of data, energy tax, and packet delivery ratio, number of dead nodes, network lifetime and delay.

Index Terms: Underwater sensor networks, sensor nodes, network coverage, connectivity, autonomous underwater vehicles, Fitness Function, Grey Wolf Optimization.

1. Introduction

Around 70% of the climate of the Planet (practically all oceans and seas) is loaded up with water. New advancements have given us better approaches for following and detecting marine biological systems. The examination, security and business utilization of sea-going climate including submerged observation, stream and ocean contamination ID and control, just as oceanography information collectivity. In a wide range of settings, the sensors innovation has developed enough for use. The business furnishes more modest sensor gadgets with diminished power utilization and better handling ability over the long haul. Likewise, present day actual sensors additionally extended the range of submerged information assortment boundaries. Moreover, a considerable lot of the sensor and sensor network capacities should be tended to in such a climate: countless hubs are required, little hub assets, brief distance radio correspondences, high inactivity range, helpless data transmission ability and high blunder rates [1, 2, 3]. Remote data transmission through the ocean is one of the enabling advances for the improvement of future ocean insight systems and sensor organizations. In present, a part of the employments of lowered acoustic correspondence are oceanography, for sifting environment, climate conditions and pollution, and transportation. In lowered condition typical resources are inspected by unmanned underwater vehicles (UUVs) and autonomous underwater vehicles (AUVs). Because of astoundingly deferred in speed, acoustic wave lowered, and huge number of multipath, there is long inspiration response and colossal time delays [4, 5, 6]. Acoustic correspondence is a critical advancement to exchange information lowered, since acoustic signs, instead of optic and radio signs, can spread in water for long reach detachments. The respectable assortment of maritime applications goes from environmental checking, defilement control, conjecture of and reaction to calamitous occasions, eco-system assessment, and perception for assurance applications and port security, offshore oil and gas industry, tank-farming, geological and oceanographic science, ocean life, science and fossil science [7, 8, 9].

One of the principal issues of each network is routing. Most UWASN concentrates on center around the physical and MAC layers. Regardless, researchers assess upper layers, for example, the organization layer, and examination in the underlying stages remains. As the principal blunder of the organization layer is to design successful and suitable submarine controlling conventions that consider the difficulties of spilling over are fundamental [10]. With the ravenous methodology, the absence of correspondence is one of the basic inquiries that administration strategies ought to have the option to address. The method for managing the correspondence void is a specific test for any enthusiastic coordinating convention. All things considered, excited coordinating conventions are made out of two modes, to be explicit, covetous mode and void dealing with mode [11, 12, 13]. If each hub makes them neighbor hub at that point, it capacities in the energetic style; in any case, it experiences a vacant mailing rundown and changes mode to void when mode is dealt with [14, 15].

2. Basics of Acoustic Communication

As noted, before, in the underwater environment the microwave, Modification of radio and optical correspondence can be utilized. For earthly contact electromagnetic signs are better since they burn-through low energy, convey high transfer speed, low inactivity in transmission and extremely low weakening in signals. Subsequently the Sinks utilize the on-shore stations radio contact mode. The high weakening which prompts extreme ingestion in light of the water conductivity, but doesn't empower radiological correspondence in the sea-going climate. In this way the range of transmissions in the sea-going climate is restricted. Likewise, a careful review line between the beneficiary and transmitter hub couples and a decent perceivability are needed to associate optically. The water flow and its turbidity make these two limitations difficult to fulfill. In this way, high information transmission over the long reach can't be cultivated by optical correspondence [16]. The acoustical contact mode is normally utilized in submarine organizations due to these challenges and limits. Anyway, in light of its characteristic limits, the handling and appropriation of information answers for land networks can't be carried out unequivocally all through the submerged organization.

3. Related Works

MSGER and MSLETR maintain a strategic distance from profundity and transmission run alteration and defeat the issue of correspondence void areas utilizing MSs, while MMS-LETR considers commotion weakening at different profundity levels, end of retransmissions utilizing multi-way correspondence and burden adjusting. The four Underwater Sensor Network (USN) routing protocols have been submitted to Shah et al.[17]: LETR, Mobile Sink–based geographical and opportunity routing (MSGER), Mobile Sink–based LETR (MSLETR) and Modified MSLETR Location errors–tough transmission range based on altered Protocol (MSTR) (MMS-LETR). For discovery of neighbouring nodes, LETR takes into account transmission levels. If a node fails to find any neighbouring node within its characteristic highest transmission, it recovers from mapping empty spaces via innovation in the adjustment of depth.

In the networks of underwater acoustic sensors Han et al. [18] has been proposed to collect stratification-based data. The network is divided into two layers in this plan based on the current Ekman drift model. The highest layer, known as the Ekman Layer, is very fast. Thus, the water stream will follow nodes in the top layer. In this case, we use a multibounce calculation based on forward delivery for the information range. Lower layer withstands a low water velocity with the objective of generally static nodes in this layer. For this information assortment, a neighbouring thickness grouping-based AUV data collection calculation is applied. By using different information assortment computations in different levels, a multihop transmission plan and an AUV-supported data assortment plan may be incorporated into the upsides to decrease network use and to increase the network life.

The authors suggested a void node routing technique for the acoustic networks underwater in [19]. The QoS parameters are used for this work: depth knowledge, time hold, residual energy and distance to the next node. This work uses the two-hop node information to prevent the empty area. The simulation was performed on MATLAB and the energy tax, the delivery ratio of the parcel and the number of dead matrices were analysed. The results of the simulation reveal that the above matrices are good in comparison with existing ones.

The energy and void-avoidable routing protocol (EAVARP) was presented for subsequent sensor networks to Wang et al. [20]. Two phases of this work. The first level is the layering and the second stage is a range of information. During the stacking phase, concentrated shells work around the sink node with sensor nodes sent on different shells. The sink node sometimes executes several levels enterprises to ensure the legality and continuity of the geographical area. EAVARP is applied in the conditions of a dynamic network. During the assortments of information, information plots are transmitted by the ODFS, regardless of the voids, depending on different concentration shells. The ODFS sees the remaining vitality and the transmission of nodes within a comparable shell and keeps cyclic transmission, floods and vacuum away. A Geospatial Geographic Routing for Interference Prevention was proposed in Underwater WSNs, Ahmed et al. [21]. Geographical direction of viewpoint seems encouraging decision-making for the data transmission in severely limited acoustic channel conditions in underwater sensor networks (UWSNs). In sparse network conditions the key test of geographic direction is non-conformity. In this particular case, we present geo-opportunistic interferences routing system (GDGOR-IA) based on geospatial spatial division, zeroing in on network obstructions. The plan is twofold, choice of target 3D Square and determination of ideal next bounce forwarder node in the objective 3D shape.

In [22], Martinez et al. are developing, constructing, and testing a compact, water-resistant and user-friendly sound recorder (USR) to track the sound and the vibration of underwater waves produced by anthropogenic activities including underwater blowing and stacking. Two hydrophones or other complex pressure sensors are used to gather data from both sensors at the same time for approximately 1 hour and 55 min. For each sensor, the gain may be set individually. Two models were introduced. The first model is a watertight, though not totally submersible, model, that can be used at up to a maximum depth of 300 m. The submerging variant is suitable for taking long-term measurements at depths involving very long hydrophone cabling or extension cables, while for short-term submerge situations the non-submersible variant is preferred. Their research reveals that the software functions as well as larger publicly usable data collection systems, and executes them. In addition, the research involves a test calculation of blast pressures when studying the impact of blasting underwater rock while also exposing young Chinook salmon and rainbow trout kept in cages to the same waves of sound and pressure. Technology defied activity in harsh conditions and is thus a useful instrument for field measurement selection.

Ardid et al. have an underwater neutrino telescope (KM3NeT) construction in [23]. Next, they used an acoustic transceiver to monitor the location of optical sensors that change due to sea waves as part of the acoustic positioning system. The transceiver has cut costs, low energy consumption, withstanding high pressures of up to 500 bar, high emission strength, low inherent noise, subjective emission signals and collected signals for functionality and processing. Second, they have installed a portable acoustic transmitter array to calibrate the noise neutrino detector system, which can represent the signature in terms of the emission path and signal form for ultra-high-energy neutrino interaction. The findings of the FFR-SX30 hydrophones and a custom sound-emissions system are met with performance. This experiment can be applied for various calibrating activities relating to acoustic emissions in underwater neutrino telescopes because of the simplicity of the transceiver system. It may also be used in other applications, such as marine navigation and implemented in various Earth-sea observatories where sensor location is a problem, in particular where highly guiding beams are needed and/or where signal processing techniques are necessary.

The paper by Baronti et al. [24] includes an electronic meter to measure seawater surface density using a magnetostrictive linear displacement sensor, which is based on the buoyance force calculation. It uses the law of Archimedes (the density of water can be measured by calculating the difference in displacements of a surface level measure and a weighted float). They describe the meter’s operating standards, its mechanical and electronic elements and its characteristics. Magnetostrictive instruments are used to calculate the displacement simultaneously. A custom electronic device with wireless communication and energy supply is the technology used. The wireless module and microcontroller firmware may be modified to allow simple use of the node in wireless networks below or above the floor. The output of a wireless density meter node using the Bluetooth laboratory and sea testing described here. Compared to the hydrometer measurements, the authors are pleased with the precision of the method. And in the loud atmosphere of sea waves, it has had a strong response.

The Ocean Bottom Seismometer (OBS) was proposed by Manuel et al. for long-term seismic studies in [25]. Low energy consumption and a high resolution and noise ratio can be saved with big data (SNR). A key element is the noise level of the acquisition system. The geophone has been built to provide optimum precision while developing the maritime seismometer system, measurement requirements, in order to let you know the difficulties of measurements (such as IEEE STD 1057 Standard for the Digitizing of Waveform Recorders and IEEE STD 1241 Standard for terms and test methods for Analog to Digital Converters). A seismic survey indicates a number of OBSs on the sea level in the area under investigation in which seismic activity, compressed vessel acoustic signals, or off-shore ocean floor displacements were reporting for analyses of seismic activity and Earth's seizure discoveries. The data sets are also used to model both the earthquake positions and the crustacean structure. The OBS can be delivered and processed in a small vessel and an oceanographic vessel is not required. It can also be utilised in marine technology, undersea research and mining research. Environmental sustainability can be determined by analysing how land use changes influence dissolved organic material (DOC) quantities and bio-availability in the aquatic environment.

The authors have suggested in [26] an energy-efficient routing algorithm to prevent void in submarine system sensors. The study is based on variance in depth and residual energy and employs two hop node data to prevent networking in the void region. It also maintains trade between the avoidance of empty areas and the consumption of energy. In terms of energy consumption and hop counts, dead nodes, PDR and copies of data packets, etc. the analyses reveal improved performance for simulation.

4. Proposed Work

The best forwarder node in the networks is given as an energy efficient optimal approach for void avoidance. Here the fitness function is calculated using a grey wolf optimization process. The selection of fitness function is based on depth difference, link quality, and number of hops. This work only considers the vertical direction. It does not consider the horizontal direction. This protocol eliminates the void locale effectively select the forwarder node which have most extreme lingering vitality, different nodes having shifting profundity. The proposed calculation deals with the premise of DBR (Depth Base Routing) and it is additionally enhanced utilizing age based bio-enlivened calculation (Gray Wolf Optimization). GWO calculation enhances the crafty way by irregular fly as per wellness till it unites to an ideal Pareto front, accordingly the network lifetime is improved. Many sink modes are appropriated consistently on a superficial level in the network structure. Since UWASNs utilizes acoustic correspondence, the postponement is generally made out of spread deferral. Initially, EEOPR picks the accompanying node reliant on the edge between the headings of engendering and vertical bearing to limits transmission delay, EEOPR first. Less edge prompts shorter transmission length, which results in less transmission disappointment. Crucial need is controlled by joining the edge and the lingering vitality. In like manner, EEOPR curtails the postponement, yet decreased the network vitality use. At the point when different applicant nodes exist at a comparable and key need, EEOPR then again sets node reliance on the connection quality. Besides, to abstain from picking a node in void district, EEOPR consolidates a recuperation strategy.

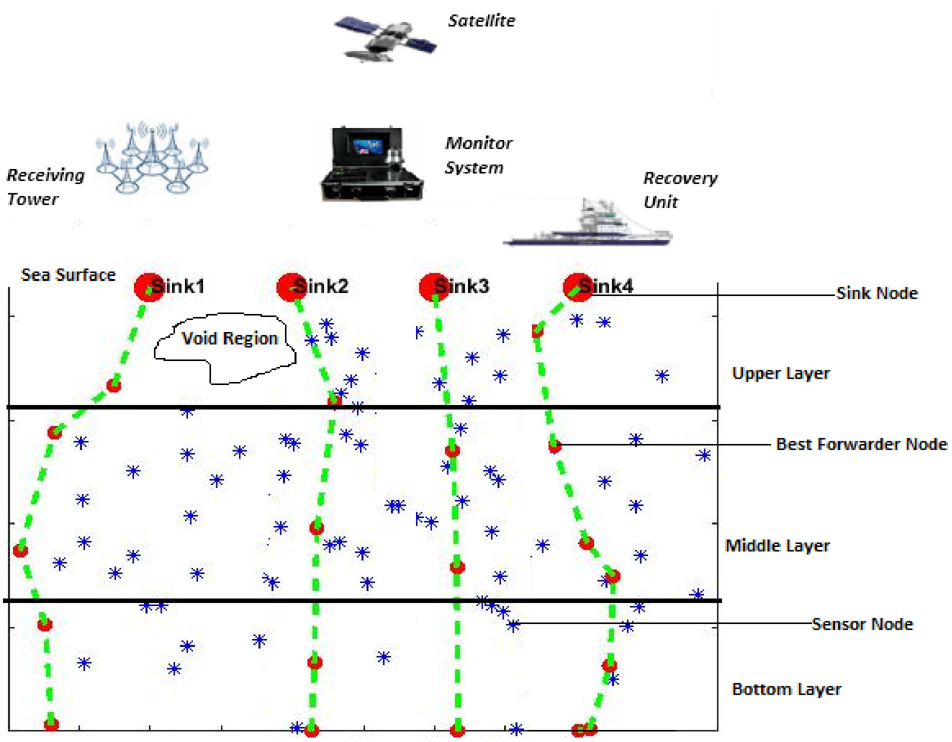

Fig.1. Routing Process of EEOPR

4.1. Working Model

The operating model comprises sensor nodes and submarines (uw-sinks). Acoustic communication is tied to each of them. As illustrated in Figure 1 many sinks are used to collect data packets from the sensor nodes on the water surface. The data packets are transmitted to each sensor node at the top layer of the sensor. It is supposed to be static in nature for all sensor nodes. The sensor nodes deployed in the undersea environment use the acoustic signal to communicate, while the sensor nodes and the uw-sinks that are used to deliver the data packets to the base station use the radio signal. As shown in figure, the whole network is divided into sub layer and in each sub layer, few sensor nodes are deployed to monitor the underwater environment. The data is transmitted from sea bed to water surface that means the proposed model only consider the vertical communication which further improves the end to end delay during data transmission.

To transmit the information at distance x from one sensor node to another sensor node, the power level is indicated by given equation 1.

$$P_1 = P_0 Att(x) \tag{1}$$

Where, P_0 represents the level of transmission power and $Att(x)$ presents the attenuation.

$$Att(x) = x^k a^x \tag{2}$$

Where, k represents the spreading factor and a represents the frequency dependent calculated by absorption coefficient.

$$a = 10^{\alpha(f)/10} \tag{3}$$

The value of $a(f)$ is calculated using below mentioned equation 7.

$$10 log_a(f) = 0.11 f^2 / (1+f^2) + 44 * f2/ (4100+f2) + 2.75 * 10^{-4} f^2 + 0.003 \tag{4}$$

To transmit one bit data packet over a distance x, the transmitter consumes the energy given by equation.

$$E_T(l, x) = lP_0 x^k a^x \tag{5}$$

In the same fashion, to receive the same data packet the receiver consumes the energy given by equation.

$$E_R(l) = lP_r \tag{6}$$

4.2. Calculation of Depth Difference

The pressure of the node is measured by P and is determined by pressing a sensor node. For computing the pressure, Equation is employed.

$$P = \rho g d \tag{7}$$

Where, ρ indicated the air density, d indicates the depth distance and g is the gravitational force. Below equation is used to calculate the depth difference which is indicated by Δd.

$$\Delta d = d_1 - d_2 = \frac{P_1 - P_2}{\rho g} \tag{8}$$

In the above expression, d1 and d2 represents the sensor node depth and neighbor sensor node depth respectively.

4.3. Residual Energy

Residual energy is the balanced amount energy available at the end of simulation. The below equation is used calculating the indicated residual energy by E_r.

$$E_R = E_0 - n_d * E_d - n_s E_s - n_r E_r - T * E_I \tag{9}$$

Where,

E_0 : Initial energy
E_d : Energy used to send the data packets
E_s : Energy used to forward reply or hello packets
E_r : Energy used to receive the data packets
T : Idle time
n_d, n_5 : Data packets and control packets transmitted
n_r : Data packet received.

The priority of the residual energy is defined using below mentioned equation.

$$P_E = \frac{E_R/E_0}{n} \tag{10}$$

4.4. *Link Quality*

There are some factors that affects the performance on acoustic communication like: noise, waves, turbulence etc. the below mentioned equations are used to calculate the power spectral density.

$$N(f) = N_t(f) + N_s(f) + N_w(f) + N_{th}(f) \tag{11}$$

$$10\log N_t(f) = 17 - 30\log f \tag{12}$$

$$10\log N_s(f) = 40 + 20(\varepsilon - 0.5) + 26\log f - 60\log(f + 0.03) \tag{13}$$

$$10\log N_w(f) = 50 + 7.5\sqrt{w} + 20\log f - 40\log(f + 0.4) \tag{14}$$

$$10\log N_{th}(f) = -15 + 20\log f \tag{15}$$

Where,
ε : Shipping factor [0 to 1]
w: Wind velocity [0 to 10 m/s]

It has been seen that noise increases as shipping, carrier frequency and wind velocity increases.
Here, Shannon theorem is used to compute the value of channel capacity.

$$C(d, f) = B\log_2(1 + SNR(d, f)) \tag{16}$$

Here, $C(d, f)$ channel capacity acts as link quality [27]. The selection of next hop is based on channel capacity and the value of SNR is $P / A(d, f)N(f)$. Here, P represents the transmission power of narrowband signal.

4.5. *GWO Algorithm*

There are lot of swarm intelligent algorithm that show the searching and hunting behaviour of animals. Out of them very few algorithms are available that have a natural leadership control. One popular algorithm named GWO proposed by [28] is available to solve the complex engineering hunting behaviour of the grey wolf inspires concerns. The hunting process of grey wolf consists of three steps: social hierarchy stratification, encircling the prey and attacking the prey. The hunting behaviour of wolf analyzed select the best node forwarder.

In the food chain, grey wolves are placed at the top where alpha, beta and delta are marked as Best, second best and third best solution accordingly best solution and rest of the solutions are marked by omega. All decisions like: sleep, wake-up and hunting is controlled by alpha. Beta is responsible to give the suggestions to alpha and also helps to take the decisions. Delta acts as hunter, scouts, and caretakers and controlled the omega wolves. In our proposed work all the wolves are considered as sensor nodes.

The equation 20-23 describes the encircling behaviour of wolves.

$$X(t+1) = Xp(t) - A.|C.Xp(t) - X(t)| \tag{17}$$

$$A = 2a.r1 - a \tag{18}$$

$$C = 2.r2 \tag{19}$$

$$a = 2 - 2(t / Max\_iter) \tag{20}$$

Where,
X: Position vector of grey wolf
Xp: Position vector of prey
t: Current iteration
a: Distance control parameter
A and C: Coefficients

r1 and r2: Random vector in [0, 1]
Max_iter: Maximum iteration

The location of prey is known to grey wolves and under the guidance of alpha, beta and delta the search process is carried out. In each iteration, the position of other agents is updated as per their position information. Below mentioned equations are used to compute the updating position.

$$X1 = X\alpha - A1.|C1.X\alpha - X| \tag{21}$$

$$X2 = X\beta - A2.|C2.X\beta - X| \tag{22}$$

$$X3 = X\delta - A3.|C3.X\delta - X| \tag{23}$$

$$X(t+1) = [X1(t) + X2(t) + X3(t)]/3 \tag{24}$$

Where,
$X\alpha$: Position vector of α wolves
$X\beta$: Position vector of β wolves
$X\delta$: Position vector of δ wolves

Here, the calculation of A1, A2 and A3 are similar to the calculation of A. In the same fashion, the calculation of C1, C2 and C3 are similar to the calculation of C.

We need to Calculate the distance between wolf and alpha, beta and delta currently candidates (Best three wolves). For the same, below mentioned equations are used.

$$D\alpha = C1.X\alpha - X \tag{25}$$

$$D\beta = C2.X\beta - X \tag{26}$$

$$D\delta = C3.X\delta - X \tag{27}$$

4.6. Fitness Function

This work calculates a fitness function based on difference in depth, residual energy and quality of connection. This fitness function is mainly designed to compute the best sponsor node in the networks. Equation 28 is used to calculate the fitness function.

$$P = [(\Delta d) + (P_E) + C(d, f)] \tag{28}$$

The greatest fitness node is considered to be the best transmitter node.

$$f(x) = \max(P) \tag{29}$$

5. Results Analysis

This section gives a detailed performance comparison of the proposed EEOPR system, in opposition to the conventional E2RV method using simulations. During simulations we found a 3-dimensional area of the network, which is 1 km wide and 2 km deep (for example, Xmax = Ymax = 1 km and Zmax = 2 km). There were different networks of 60, 90 and 180 nodes in the simulations. The transmission is homogeneous to all nodes between 600 m and 1000 m. The sparsely and densely of the network can be seen with sufficient parameters.

In each simulation scenario, the remaining nodes are randomly installed and sink node. These nodes act as the transmitters or the transmission nodes of the data source to the system (s). This standard scenario shows clearly how the load is relayed the shipping scheme is distributed among shippers. The first simulation experiment includes 60 nodes excluding the data source put randomly in the network region. The first 60 nodes are unchanged and in the next 90 node trial, only the next 30 nodes are placed randomly on the network. There are five sinks on the surface of the network area. For the duration of the simulation, the entire network is deemed static.

The parameters of the files, control traffic and acoustical network used for the simulations are 88-bit and 576-bit header and payload size for data packets. The request from the neighbor and the recognition is 48 bits. The basic 88-bit header is used for all simulation packet types. The simulations also considered the delay in acoustic propagation of 1500 m and the data rate of 16 x 103 bit per second. Finally, at layer MAC, pure ALOHA is used due to its lack of delaying and the lack of collision detection and prevention mechanisms. As previously mentioned, the source node is deployed and data packets for the sink node are generated (s). The average generation of data packets is 0.2 packets per second or one packet per five seconds. There are also certain constants, e.g. the weighting factor α and the global parameters μ, used by the E2RV algorithm. The value α = [0, 1] prioritizes the variations in depth in the E2RV holding-time measurement (between the sender and the receiving node and the receiver itself and its lower depth neighbour). We have used α = 0.5 for fair treatment of the two depth variations. Similarly, the global parameter β was used to guarantee that the time between the two nodes was sufficiently high to ensure the removal of the packet. Around 100 simulations (a network with a certain number of nodes and a transmission range) of a single network scenario are conducted.

5.1. Total forwarded Copies of Data Packet

The number of copies delivered to the network for each data packet transfer initiated by the source node is the initial measure of the performance of the system. Figures 2 and 3 exhibit complete copies of transmitted network data packets for different size networks and transmission ranges. Figure 2 shows that the number of transmitted copies of network data packets is linearly proportional to the size of the network in the fixed transmittal range. This becomes apparent when a big network can include many duplicate data packet transmissions. Because the limited network size and the constrained transmission range do not reach the entire network, more copies of data packets are spread across the entire area of the network with the increasing number of network dimensions. When the network size increases among their next Hop neighbour, distinct nodes with a similar difference in depth and depth are very likely. As a result, their predicted holding times are almost similar to increasing data packet traffic. The second intriguing pattern is the inverse proportion of the number of copies of the data packets sent within the fixed network dimension scenario. This effect is particularly apparent since the removal of packets in many network nodes increases as the transmission range is increased, see Figure 3. However, the perfect deletion of packets cannot be achieved if only one node inside ts transfers the data packet. Due to the increased density of the node within the transmission range the possibilities of a packet collision grow. This effect is particularly apparent since the removal of packets in many network nodes increases as the transmission range is increased, see Figure 3. However, the perfect deletion of packets cannot be achieved if only one node inside ts transfers the data packet. Due to the increased density of the node within the transmission range the possibilities of a packet collision grow. It shows that EEOPR propagates approximately 49 percent less copies of the data packet for the larger network size and transmission range than the E2RV. From this assessment, the EEOPR clearly minimizes the data dissemination storm for different network sizes and transmission ranges.

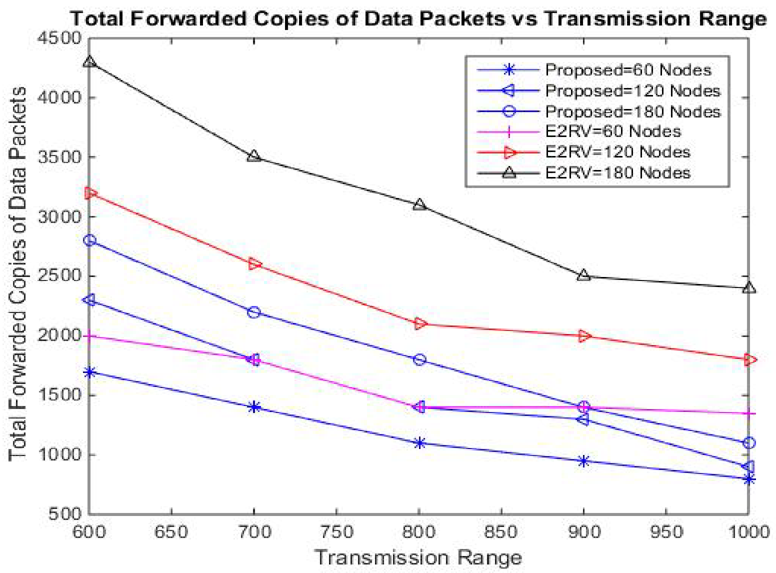

Fig.2. Total Forwarded Copies of Data Packets vs Transmission Range

5.2. Packet Delivery Ratio (PDR)

The primary aim of any routing or forwarding system is to enhance various network and PDR efficiency metrics. Therefore, the PDR efficiency metric for the EEOPR method has also been analyzed and discussed. The EEOPR and E2RV PDR output are shown in Figures 4 and 5 for different transmission range and different. With the transmission range also increasing the node density, figure 4 shows the fixed network size and variable transmission range scenario. This improves the possibility of properly passing the data packets to the sink by eliminating a large number of redundancies and reducing the hops between the source and the sink(s). This deletion and decrease of the hop distance boosts network life, does not instantly establish a void region and more packets are successfully transmitted to the sink. Figure 5 shows that the EEOPR PDR has improved in contrast to the E2RV for several networks. As we talked about the event previously, the network size of the fixing transmission range is directly proportionate that are transmitted network-wide. The likelihood of a packet collision becomes high due to the massive data packet transfers, and the energy from the intermediate relay nodes rapidly decreases. As the battery capacity of most intermediate nodes in the forwarder is shrinking, packets cannot be forwarded. As EEOPR chooses transmission models equally, by using their leftover normalized energy in the holding time calculation it avoids punishing the low battery power nodes of the network. The EEOPR network therefore endures more than the E2RV. This section analyses and discusses energy consumption and the number of dead nodes. The dead knots provide an empty area and/or a layer which entirely separates the source node from the sink (s). These actions together lead to a severe decline in the PDR. In addition, the PDR of EEOPR, as with E2RV, is either always or slightly increasing with an increase in network dimensions.

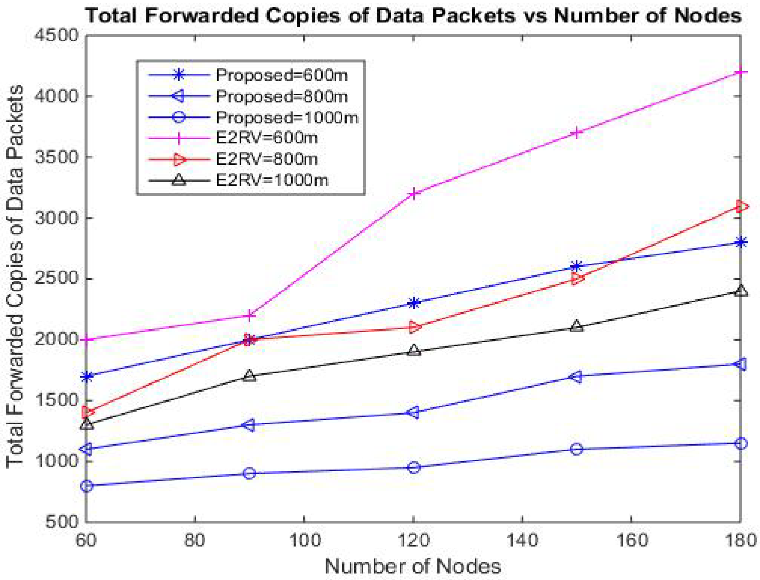

Fig.3. Total Forwarded Copies of Data Packets vs Number of Nodes

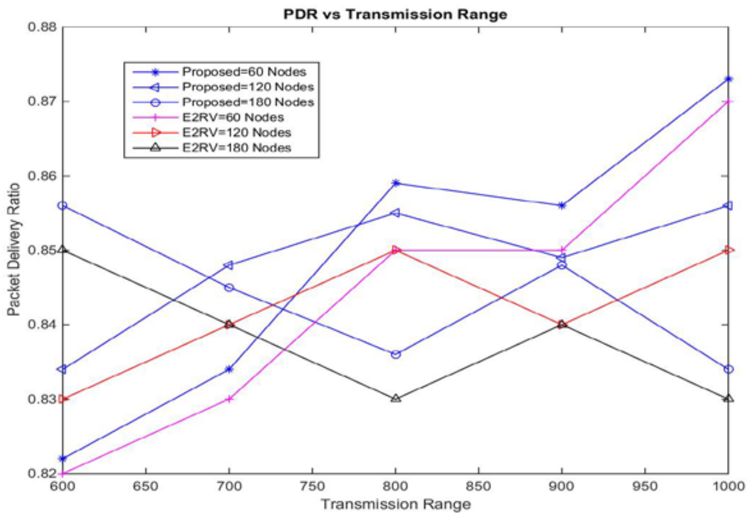

Fig.4. PDR vs Transmission Range

5.3. Energy Tax

Figures 6 and 7, respectively, demonstrate the energy tax analysis by EEOPR for various network and transmission sizes. It indicates that for various network sizes the energy tax of the EEOPR is much lower than the E2RV. As a consequence, relative to the EEOPR system, it has an exceptionally low energy levy. It should be noted, however that the trend in energy tax for both schemes rise marginally with the network size increasing. That is because big copies of data are communicated with the energy spent and the amount of data packets generated from the source node is very high for all network sizes. In addition, the simulations demonstrated a considerable effect on the network's total energy use by transmitting and receiving these data packets.

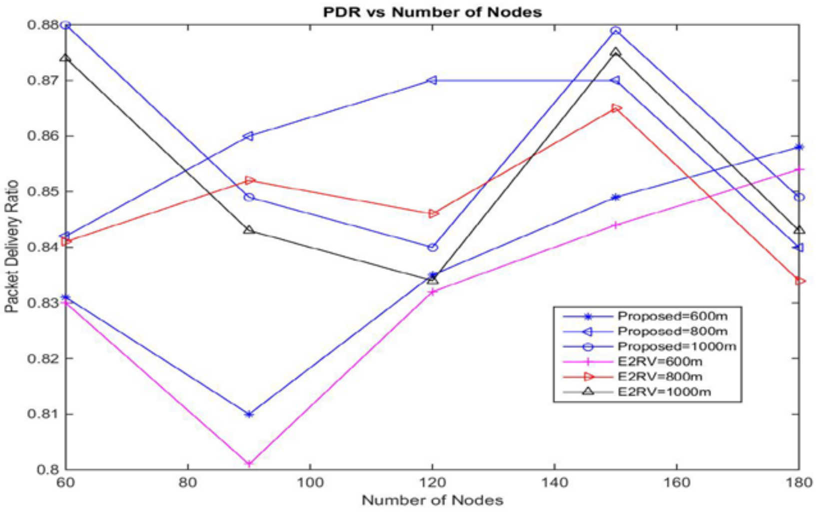

Fig.5. PDR vs Number of Nodes

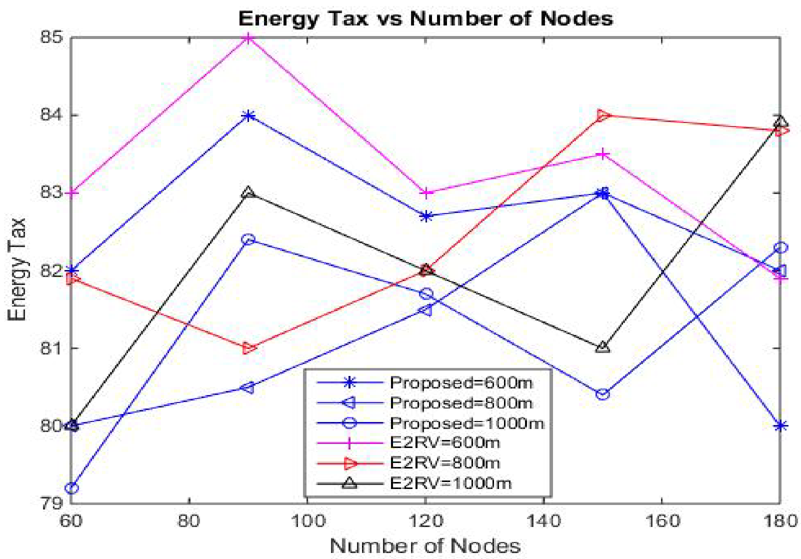

Fig.6. Energy Tax vs Number of Nodes

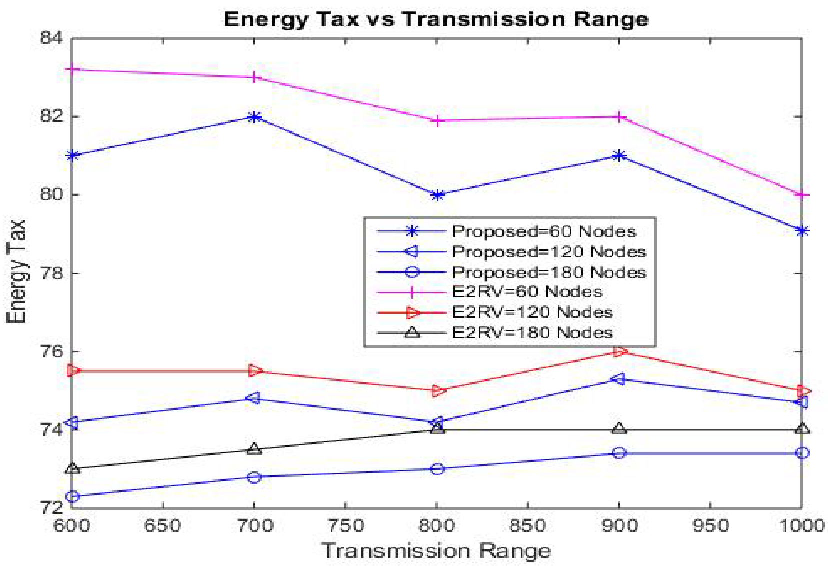

Fig.7. Energy Tax vs Transmission Range

5.4. *Number of Dead Nodes*

When a node is completely exhausted and cannot participate in a data transmission process, the node is considered dead. Figure 8 shows an average dead node number for different network sizes and stationary transmission ranges. It indicates that, due to the vast number of nodes involved, the number of dead nodes increases with the size of the network. In all network conditions of different network sizes, the number of nodes in EEOPR is smaller than the E2RV.

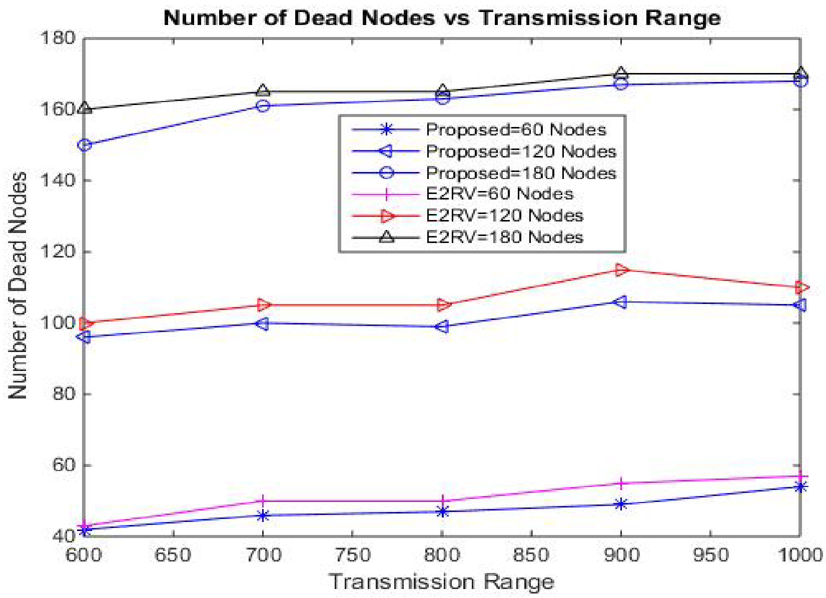

Fig.8. Number of Dead Nodes vs Transmission Range

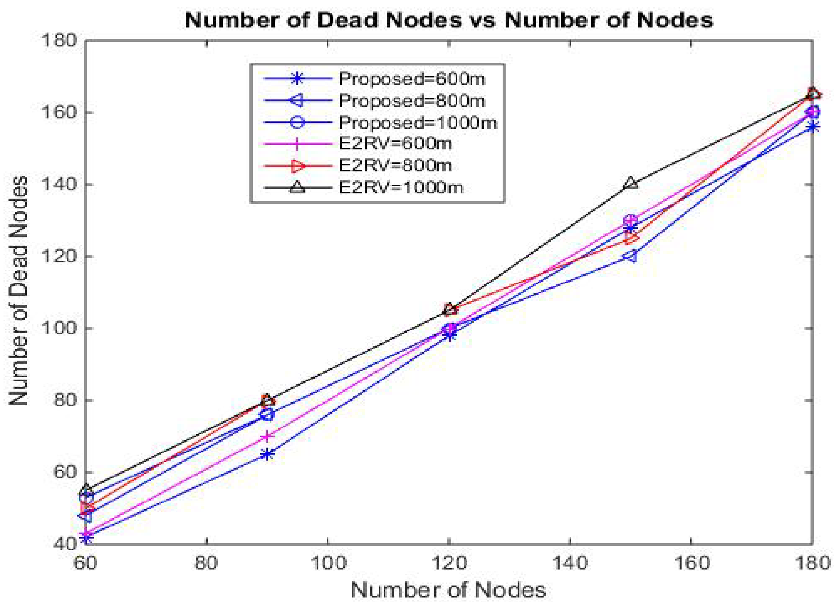

Fig.9. Number of Dead Nodes vs Number of Nodes

Moreover, an average number of dead nodes with a given grid size and different transmission ranges were simulated in the simulation as shown in Figure 9. The number of dead nodes increases as the transmission range alone increases dramatically increase of the data packet traffic. The figure, however, shows that EEPOR has significantly fewer dead nodes than the E2RV. A main factor is the number of dead nodes. However, when these nodes die during the simulation, the key factor is the time case. If they die before the simulation, they cannot properly participate in the process of transfer of the data packet.

5.5. *Hop Count*

The average hops for different transmission ranges and fixed network sizes is shown in figure 10. These statistics indicate that the EEPOR number is much higher than the E2RV. The explanation behind EEPOR's slightly larger hop is that it focuses on reducing the energy usage of the network and increasing the life of the network. This is done by EEOPR, as it uses the residual energy of the node, the variation of the depths of the adjacent nodes and the difference in depth between transmitting, receiving or receiving transmitters.

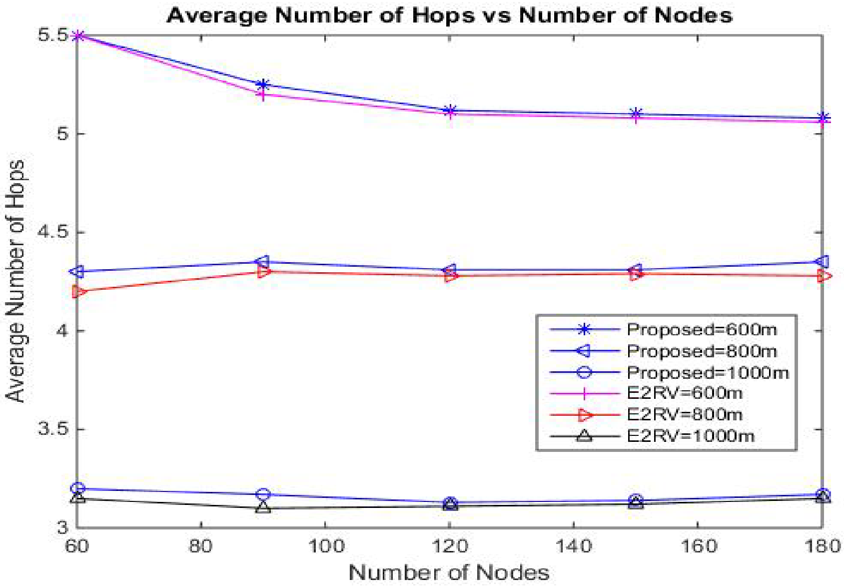

Fig.10. Average Number of Hops vs Number of Nodes

6. Conclusion

The research proposed an algorithm based on profundity difference, residual energy and connection quality for avoiding nodes. This piece leverages the profound contrast between its one-hop neighbour and its one-hop neighbour transmitters (that are two-hop neighbour of the Sender node). In addition, the priority is to measure the holding period using the standardized residual forwarder energy and the standards of the two hop forwarders. This delivers energy equity, transmits data transfer costs across density knots that are suitably distributed and increases network life. The simulation was done on MATLAB where the simulation findings indicate that EEOPR propagates approximately 49 percent less data packet copy, increases network life by over 42(s), decreases node energy depletion. This approach has a slightly greater delay instead of selfish depth transport, since it is based on energy fairness and load balance.

References

[1] Mistry, Kosha, and HardikModi. "Design of high data rate and multipath efficient underwater acoustic communication system using OFDM–DQPSK." In Proceedings of international conference on ICT for sustainable development, pp. 493-502. Springer, Singapore, 2016.

[2] Gupta, B., Gola, K.K. & Dhingra, M. HEPSO: an efficient sensor node redeployment strategy based on hybrid optimization algorithm in UWASN. Wireless Netw 27, 2365–2381 (2021). https://doi.org/10.1007/s11276-021-02584-4.

[3] Sharad Saxena, Shailendra Mishra, Mayank Singh,"Clustering Based on Node Density in Heterogeneous Under-Water Sensor Network", International Journal of Information Technology and Computer Science, vol.5, no.7, pp.49-55, 2013.

[4] K. Kumar Gola, N. Chaurasia, B. Gupta and D. Singh Niranjan, "Sea lion optimization algorithm based node deployment strategy in underwater acoustic sensor network", International Journal of Communication Systems, vol. 34, no. 5, 2021. Available: 10.1002/dac.4723.

[5] Gola, K., & Gupta, B. (2020). Underwater sensor networks: Comparative analysis on applications, deployment and routing techniques. IET Communications, 14(17), 2859-2870. https://doi.org/10.1049/iet-com.2019.1171.

[6] Md. Ashrafuddin, Md. Manowarul Islam, Md. Mamun-or-Rashid, "Energy Efficient Fitness Based Routing Protocol for Underwater Sensor Network", International Journal of Intelligent Systems and Applications, vol.5, no.6, pp.61-69, 2013.

[7] Basagni, Stefano, Chiara Petrioli, Roberto Petroccia, and Daniele Spaccini. "CARP: A channel-aware routing protocol for underwater acoustic wireless networks." Ad Hoc Networks 34 (2015): 92-104.

[8] K. Gola and B. Gupta, "Underwater Sensor Networks Routing (UWSN-R): A Comprehensive Survey", Sensor Letters, vol. 15, no. 11, pp. 877-890, 2017. Available: 10.1166/sl.2017.3896.

[9] Garcia, J. Esteban. "Positioning of sensors in underwater acoustic networks." In Proceedings of OCEANS 2005 MTS/IEEE, pp. 2088-2092. IEEE, 2005.

[10] Yoon, Seokhoon, Abul K. Azad, Hoon Oh, and Sunghwan Kim. "AURP: An AUV-aided underwater routing protocol for

underwater acoustic sensor networks." Sensors 12, no. 2 (2012): 1827-1845.
[11] Jornet, JosepMiquel, MilicaStojanovic, and Michele Zorzi. "Focused beam routing protocol for underwater acoustic networks." In Proceedings of the third ACM international workshop on Underwater Networks, pp. 75-82. ACM, 2008.
[12] Lee, Uichin, Paul Wang, Youngtae Noh, Luiz FM Vieira, Mario Gerla, and Jun-Hong Cui. "Pressure routing for underwater sensor networks." In 2010 Proceedings IEEE INFOCOM, pp. 1-9. IEEE, 2010.
[13] Climent, Salvador, Antonio Sanchez, Juan Capella, Nirvana Meratnia, and Juan Serrano. "Underwater acoustic wireless sensor networks: advances and future trends in physical, MAC and routing layers." Sensors 14, no. 1 (2014): 795-833.
[14] Climent, Salvador, Antonio Sanchez, Juan Capella, Nirvana Meratnia, and Juan Serrano. "Underwater acoustic wireless sensor networks: advances and future trends in physical, MAC and routing layers." Sensors 14, no. 1 (2014): 795-833.
[15] Zhang, Song, Deshi Li, and Jian Chen. "A link-state based adaptive feedback routing for underwater acoustic sensor networks." IEEE Sensors Journal 13, no. 11 (2013): 4402-4412.
[16] Coutinho, Rodolfo WL, AzzedineBoukerche, Luiz FM Vieira, and Antonio AF Loureiro. "GEDAR: geographic and opportunistic routing protocol with depth adjustment for mobile underwater sensor networks." In 2014 IEEE International Conference on communications (ICC), pp. 251-256. IEEE, 2014.
[17] Shah, Mehreen, ZahidWadud, Arshad Sher, Mahmood Ashraf, Zahoor Ali Khan, and Nadeem Javaid. "Position adjustment–based location error–resilient geo-opportunistic routing for void hole avoidance in underwater sensor networks." Concurrency and Computation: Practice and Experience, vol. 30, no. 21 (2018): e4772.
[18] Han, Guangjie, SongjieShen, Houbing Song, Tao Yang, and Wenbo Zhang. "A stratification-based data collection scheme in underwater acoustic sensor networks." IEEE Transactions on Vehicular Technology, vol. 67, no. 11 (2018): 10671-10682.
[19] Gola, K.K.; Gupta, B.: An energy-efficient quality of service (QoS) parameter-based void avoidance routing technique for underwater sensor networks. Jordan. J. Comput. Inf. Technol. 5(3), 244–262 (2019).
[20] Wang, Zhuo, Guangjie Han, Hongde Qin, Suping Zhang, and Yancheng Sui. "An energy-aware and void-avoidable routing protocol for underwater sensor networks." IEEE Access 6 (2018): 7792-7801.
[21] Ahmed, Farwa, NadeemJavaid, Zahid Wadud, Arshad Sher, and Sheeraz Ahmed. "Geospatial Division Based Geographic Routing for Interference Avoidance in Underwater WSNs." In Recent Trends and Advances in Wireless and IoT-enabled Networks, pp. 207-214. Springer, Cham, 2019.
[22] Martinez, J.J.; Myers, J.R.; Carlson, T.J.; Deng, Z.D.; Rohrer, J.S.; Caviggia, K.A.; Woodley, C.M.; Weiland, M.A. Design and Implementation of an Underwater Sound Recording Device. Sensors 2011, 11, 8519–8535.
[23] Ardid, M.; Martínez-Mora, J.A.; Bou-Cabo, M.; Larosa, G.; Adrián-Martínez, S.; Llorens, C.D. Acoustic Transmitters for Underwater Neutrino Telescopes. Sensors 2012, 12, 4113–4132.
[24] Baronti, F.; Fantechi, G.; Roncella, R.; Saletti, R. Wireless Sensor Node for Surface Seawater Density Measurements. Sensors 2012, 12, 2954–2968.
[25] Mànuel, A.; Roset, X.; Rio, J.D.; Toma, D.M.; Carreras, N.; Panahi, S.S.; Garcia-Benadí, A.; Owen, T.; Cadena, J. Ocean Bottom Seismometer: Design and Test of a Measurement System for Marine Seismology. Sensors 2012, 12, 3693–3719.
[26] G. Khan and R. K. Dwivedi, "Energy-Efficient Routing Algorithm for Void Avoidance in UWSNs Using Residual Energy and Depth Variance (E2RV)," IJCNC, vol. 10, no. 4, pp. 61-78, July 2018.
[27] Li M, Du X, Liu X, Li C. Shortest Path Routing Protocol Based on the Vertical Angle for Underwater Acoustic Networks. Journal of Sensors. 2019.
[28] Mirjalili S, Saremi S, Mirjalili SM, Coelho LD. Multi-objective grey wolf optimizer: a novel algorithm for multi-criterion optimization. Expert Systems with Applications. 2016 Apr 1;47: 106-19.

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