AN INNOVATIVE ENERGY BALANCED ROUTING APPROACH FOR VOID HOLE AVOIDANCE IN UNDERWATER ACOUSTIC SENSOR NETWORK

A Thesis

Submitted towards the Requirements for the Award of Degree of

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IN

COMPUTER SCIENCE AND ENGINEERING

Under the Faculty of Computer Science and Engineering and Technology

Submitted By

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2026

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Dedicated

To

My Beloved Parents

Whose blessings & love, brought me to this level.....

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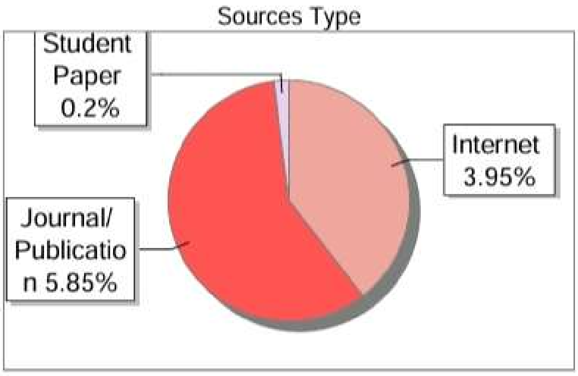

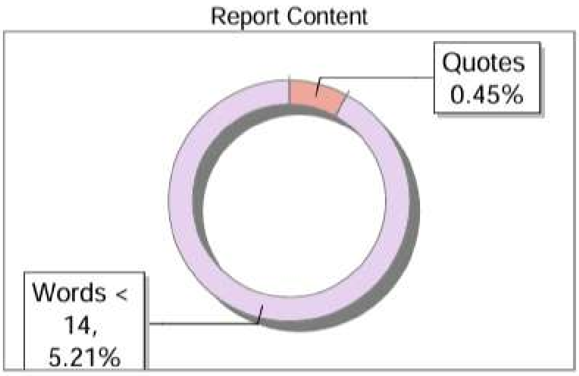

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TABLE OF C O N T E N T S

LIST OF FIGURES

LIST OF TABLES

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 issue 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 consider 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.

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

INTRODUCTION

1.1 Introduction

The vast majority of Earth's atmosphere, or around 70%, is water. This opens up new avenues for marine ecosystem monitoring and sensing. The development of sensor technology has been phenomenal, and it is currently used in a myriad of contexts. Eventually, the product will lead to smaller sensor devices with better processing capability or reduced power usage [2]. There is now a much broader variety of elements for gathering data underwater thanks to modern physical sensors. Many sensor and sensor network tasks must be addressed in this environment, such as the following: a high error rate, a restricted bandwidth capacity, a short range for radio communications, a high latency range, and a large number of nodes.

At now, oceanography, transportation, and the filtering of weather, air, and pollutants all make use of submerged acoustic correspondence. Extremely low speed, underwater sound waves, and a multitude of multiple pathways all contribute to lengthy motivating responses and substantial time lags [3]. An important step forward in submerged data interchange is audio communication, as acoustic signals, unlike optic and radio signals, may travel under water for long distances. Seagoing applications cover a wide range of fields, including hydroponics, oceanography, marine biology, palaeontology, ecological monitoring, contamination control, disaster prediction and response, eco-framework analysis, protection applications, and port security, among many more. However, additional difficulties arise when constructing a UASN as a result of the power constraints of submerged sensing nodes in relation to the dangerous aspects at the submerged acoustic channel, such as poor data transmission, multi-way impact, blurring, considerable engendering deferral, and a high piece error rate.

When building the UASN protocol stack, it is important to read up on a variety of topics, including the process of data or information movement inside a network, namely steering, as well as other interesting and novel areas of study [5]. It is quite difficult to provide adaptable and competent directing assistance in UASNs because of the fascinating characteristics of submerged sensor organisations. In UASNs, designing routing protocols is a popular topic of research. Data transmission efficiency and reliability are guaranteed via a scheduling mechanism. When compared to Wireless Sensor Networks, the complicated and limited transmission method design of UASNs is a result of differences between terrestrial and underwater settings [6]. Two problems, firstly, water currents that cause nodes to move continually and secondly, the significant propagation latency, in the comprehensive study over the creation and deployment of UASN, make underwater localisation discovery exceedingly inaccurate. [7] Tested a wide range of routing-based protocol characteristics, such as transmission method, data copies, clustering, control packets, single/multiple sinks, etc. There was also a breakdown of the features and concepts of several routing protocols. Vulnerabilities in the system lead to complicated packet routing issues. Dispersion or failure of sensor nodes leads the system to lose insight [8]. A transducer is used to send and receive ultrasonic waves in order to reduce the power consumption and voltage of UASNs. The high cost, limited geographical coverage, and lack of nodes in sensor networks all contribute to their empty spaces [9]. On the other hand, repositioning the node at that moment can generate the empty space. The many void management approaches that routing ideas of sensor networks have embraced may be broadly categorized into two groups: backpressure rule and right-hand rule [10]. As a result, effective methods for routing protocols to fill in gaps in UASN transactions must be explicitly designed.

1.2 Background

The most current developments in UASN with respect to protocol design, research technique, and the difficulties caused by the vacuum are discussed in the paper in [11]. Instead of relying on a location-based protocol to fix this, the approach relies on received signals, which is problematic. The size of the vector represents the beeper signal approaching the sink, and the sensor node initially creates the line independently at the when using SSR.The application for the next hop is given precedence to the node that is constructed closest to the vector. One approach stays away from empty spaces so data packets don't get to surrounding nodes. Using SSR effectively lowers E-ED and energy usage. Military research, resource discovery, pollution monitoring, coastal aquatic atmosphere monitoring, and disaster prevention are just a few of the many UASN uses. From the node that links the sink to the base, USWN uses the inference aware routing protocol to follow the paths from beginning to finish. The Void Hole Problem is avoided via Inference Aware Routing as opposed to Depth-Based Routing. Energy Efficiency is used by USWN to integrate the forwarding and transmission mechanisms that transfer data from the source node to the sink node, Interference, and Route Aware protocol. By using the optimal relay, reducing the number of hops, and implementing shortest route follow-up, this technique achieved better energy efficiency than the DBR in terms of structure [12]. Energy consumption is homogeneous across sensor nodes using the ODBR method.

To improve packet delivery in UASNs while minimising energy and delay cost, many routing protocols have been proposed, the most prominent of which are greedy routing techniques. In sensor and ad hoc networks that use localisation technologies, geographically greedy routing has come up as a possible strategy. With geographic greedy routing, data is sent forward and to the end destination using position data at each hop. [13].

With geographic direction, every node will discover the one that is geographically nearest to the destination location using a greedy-forwarding method. Regrettably, connectivity problems or the local maximum phenomenon could cause greedy forwarding to fail. Optimal routing between source and destination is no guarantee that a packet won't be lost if the forwarding node is unable to locate any eligible nodes en route. The void phenomenon is caused by a combination of variables, including a sparse topology, transient impediments, and unstable node connection.

The void problem may be partially or totally resolved by increasing the network's density; however, this isn't always possible. Wireless and ad hoc network holes may be filled using a variety of strategies, including restoration methods, which can improve route efficacy. cited as [14]. Additionally, the void may be moved as the majority of nodes in the ocean are also moveable.

External factors might also contribute to a mobile vacuum. When a ship navigates through an underwater network, it might disrupt communications in the area or cause a gap to form that other ships can't follow. In general, operating in mobile, three-dimensional holes is much more difficult for the properties that use underwater sensor networks.

1. Underwater Communication Channel: Severe attenuation, dispersion, and multipath effects are caused by the very unexpected and harsh conditions under the hydro channel. An increase in bit error rate, packet loss, and end-to-end latency are all ways in which this channel behaviour might degrade UWSN performance.

2. Node Deployment: Node deployment is one factor that significantly affects network performance. System and connection architecture, influenced by node location, affects routing efficiency, energy consumption, and network longevity.

3. Mobility: Nodes in some UWSN applications may be in motion, such underwater vehicles or aquatic creatures. Topology, connection, and routing in a network are all impacted by the connectors' velocities. Consequently, UWSNs must address the critical issue of mobility management.

4. Energy Consumption: Especially in distributed systems like WSNs, power consumption is a key factor determining the network's lifetime. The power capacities of underwater network nodes are severely limited since they depend on batteries. Protocols, algorithms, and techniques that reduce energy consumption are crucial for network longevity.

5. Data Aggregation and Routing: The underwater environment poses specific problems for Underwater Wireless Sensor Networks (UWSNs), including communication reliability, energy consumption, and network longevity. Efficient data distribution requires routing techniques that can handle the challenging underwater communication channel and the mobility of nodes.

6. Security: Eavesdropping, jamming, and node penetration are just a few of the security issues that UWSNs are susceptible to. To prevent these dangers, UWSNs must have security measures in place, including authentication, encryption, and intrusion detection.

7. Environmental Factors: The efficiency of UWSNs is susceptible to environmental influences like salinity, water temperature, and pressure. These

factors may alter the underwater communication channel's behaviour and the nodes' chemical and physical properties. Monitoring the surrounding environment is crucial for ensuring the dependability of UWSNs.

1.3 Application of UASNs

While networks had been around for quite some time in marine settings, it wasn't until technology advanced in the early 1900s that they were really put to use.

Since then, the utilisation of submerged acoustic sensor networks has skyrocketed, and they can now perform the vast majority of duties formerly performed by terrestrial systems of wireless monitoring devices in marine environments. One way to categorise underwater network applications is by the domains in which they operate,

Military applications: The primary function of ultrasonic range finders (UW-ASNs) in these applications is to detect and identify targets, such as underwater obstacles or subs, as is common practice in military mine and submarine detection and fishing operations[21].

Environmental applications: Underwater mobile position and speed measurements are one use case for UW-ASNs, but they may also be used to a wide variety of marine environment variables, such as bottom topography, living species, currents, hydrological systems, and so o. [22]

Scientific applications: Among these uses for UW-ASNs include the transmission of signals to remotely controlled devices, communication between submarines and surface ships, and signals that underwater scientific equipment may pick up [23].

Underwater exploration: Here, UW-ASNs facilitate mineral exploration, assist locate oil reserves or reservoirs, and choose locations for underwater cables[24].

Surveillance and disaster prevention:

The use of a water sensor might allow for the retargeting, monitoring, and penetration testing of such systems. Seismic activity may be measured by the UW-ASNs, which helps with tsunami warnings and research into the impacts of earthquakes that happen beneath the sea.[25].

Table 1.1 UWSNs Applications

Application	Description	Advantages	Challenges
Oceanographic data collection	Numerous oceanographic characteristics, including temperature, salinity, and current velocity, can be observed using UWSNs.	Long-term monitoring, real-time data collection, reduced cost and risk compared to traditional methods.	Limited energy and communication resources, harsh and unpredictable underwater environment, difficult deployment and maintenance.
Underwater surveillance	UWSNs can be used to detect and track underwater objects, such as submarines or marine wildlife.	Wide area coverage, low cost and power consumption, ability to operate in harsh environments.	Limited range and data rate, susceptibility to interference and noise, false alarms and missed detections.
Underwater navigation	UWSNs facilitate underwater navigation and positioning, either by providing landmarks or by transmitting signals for acoustic positioning.	Accurate and reliable navigation, reduced risk and cost compared to traditional methods, potential for real-time positioning.	Limited range and accuracy, susceptibility to interference and noise, need for synchronization and calibration.
Underwater environmental monitoring	UWSNs can be helpful in monitoring the health and quality of underwater ecosystems, by measuring parameters such as pH, dissolved oxygen, and nutrient levels.	Improved understanding and management of marine environments, potential for early warning of environmental threats.	Limited energy and communication resources, need for sensor calibration and maintenance, variability of environmental conditions.

1.4 Underwater Acoustic Sensor Networks Architecture [20]

One subset of acoustic sensor networks developed specifically for use in watery habitats is the underwater sensor network, or UWSN. Since transmitting radio waves or optical signals underwater is not feasible, UWSNs rely on acoustic communication instead. This enables us to collect data and information about the ocean for various uses, such as monitoring environmental conditions, detecting seismic activity, keeping tabs on oceanographic data, and real-time tracking of ships.

1-D UASN Architecture: Deploying sensor nodes in a methodical manner enables each node to independently develop its own network. In this design, each node is in charge of gathering data and transmitting it to a remote location. The most common method of communication in such a network is star connectivity, in which all nodes transmit data directly to the base station after a single hop. Complex auditory environments are notoriously difficult to cover with one-dimensional UASN because of their poor connection stability and transmission range. Whether a network uses acoustic channels, optical communication, or radio frequency, all of its components adhere to a one-dimensional structure. Therefore, it does not excel at handling massive amounts of data.

2-D UASN Architecture

Within the framework of UASNs' multi-dimensional design, we label the network as 2-D, 3-D, or 4-D. We use clusters at this design to put the monitoring terminals at deep in the ocean. One or more underwater sinks are included into this design to gather data from the ocean floor and transmit it to the surface. The use of both horizontal and vertical acoustic transceivers allowed us to achieve this. Horizontal transceivers allow for data collection, instruction delivery, and equipment and uw-sink detector customisation. When transmitting data to ground stations across large distances, the term "horizontal transceiver" is used. Communication in two-dimensional underwater sensor networks is often accomplished using optical, radio frequency, or acoustic transmission. After considering the underwater application, we choose the topology, which might be a star, ring, or two-dimensional mesh.

3-D UASN Architecture:

Using a three-dimensional spatial framework and a maritime environment with varied depths, a complicated network of wireless nodes is developed to function. Sampling the three-dimensional space at the same time has its benefits. All of the cluster heads are collecting data in this configuration, and it is sent to the base station via its linked member. The core concept of the cluster is work division. The sensitivity node and the foundation node engage in intra-cluster communication, one of three possible types of communication between nodes in a cluster. Second, groups of nodes operating at various depths may communicate with one another; third, buoyant anchors can communicate with one another.

4-D UASN Architecture: With this layout, it would seem as if the business used both stationary and mobile 3-D underwater sensor networks. Underwater sensor networks that are mobile collect data from anchor nodes and transmit it to a distant site or base station by remotely operated vehicles. Autonomous vehicles, submersibles, boats, or underwater robotics might all be examples of such modes of transportation. Every sensor node can send data straight to the ROVs if it's close enough to them. The kind of communication that may be formed between underwater sensor nodes and ROVs—RF, optical, or acoustic—depends on the information and distance in an underwater environment. If a sensor node is far from ROVs and doesn't have much data, it can use an acoustic link; otherwise, it can use a radio connection.

Every architectural style has its advantages and disadvantages, and the one that's best chosen is determined by the specific requirements of the project. In contrast to 1-D designs, 3-D structures may be more appropriate for some applications, such as underwater navigation. Different designs may utilise different networking and communication protocols due to factors such as the sensors used and the nature of the surrounding environment.

1.5 Design Issues in UWSNs

Connected Wireless Sensor Systems for Underwater Wireless Sensor Networks (UWSNs) to function reliably and efficiently, certain design considerations are required. A few of the most critical concerns with the design are these:

1. Medium of communication: Water's complex qualities make it a challenging medium for wireless communication, since it absorbs, scatters, and reflects electromagnetic waves. Universal wireless sensor networks (UWSNs) use sound-based communication, which has limitations such as multiple data transmission pathways, Doppler shift, and interference from ambient noise.

2. Energy efficiency: Energy management is of the utmost importance in UWSNs since the sensor nodes' batteries are frequently non-rechargeable and have limited capacity. Energy efficiency is maximized via the application of various techniques and procedures.

3. Localization: Many UWSN applications, such underwater navigation and object tracking, rely on precise localization. Nevertheless, environmental conditions like waves and currents make underwater localization a difficult process due to the complicated propagation of audio signals in water.

4. Mobility: Sensors and vehicles operating underwater are vulnerable to a wide range of motions, including as currents, turbulence, and drift. Adapting to node mobility and dynamic topology is crucial while designing algorithms and protocols for UWSNs. To keep UWSNs running well and for a long time to come, energy-efficient media access control (MAC) protocols, mobility prediction algorithms, adaptive routing, and dynamic clustering are must-haves. These methods are designed to be resilient in the harsh underwater conditions, utilize energy efficiently, and provide dependable communication. Reliability in communication and energy efficiency in operation are two of the most important scalability considerations for UWSNs, which may include a vast array of sensors and vehicles.

5. Data aggregation: The massive amounts of data produced by sensors and vehicles make efficient data aggregation approaches crucial for UWSN management. Efficiency in energy consumption, data dependability, and bandwidth utilisation may all be enhanced with the use of these methods. Enhancing performance and durability of UWSNs may be achieved by data aggregation methods, which tackle issues including synchronization, node mobility, and energy efficiency.

6. Security: Attacks such as eavesdropping, manipulation, and denial-of-service are possible on UWSNs. Data must be protected in three ways: availability, integrity, and secrecy.

7. Environmental monitoring: When planning UWSNs for use in environmental monitoring, it is important to take into account variables like temperature, salinity, and pH. For efficient, accurate, and dependable monitoring, it is necessary to have well-designed sensors, adaptive algorithms, communication protocols that minimise energy use, and methods for effectively aggregating and processing data. Insights into water quality and habitat health may be provided by UWSNs by taking these elements into account, which can aid in the protection and management of aquatic habitats.

Underwater acoustics, signal processing, communication protocols, localization, and energy management are just a few of the many fields that must be considered in a multidisciplinary approach while designing UWSNs.

1.6 Main Contribution

I. i) We also take a look at depth or pressure routing techniques, localization-based and localization-free routing protocols, and the void avoidance protocol algorithm because of how it can improve UASN's routing performance.

II.

III. ii) Mobility-related localisation protocols are a rich source of ideas for new routing protocols since they are themselves subdivided into other protocols.

IV. Using depth and position data collected by underwater acoustic sensor networks (UASNs), we examine the features of void management.

V. iv) When sensor node communication fails, talk about void avoidance, its pros and cons, and how to improve the forwarding strategy.

VI. Acoustic sensor networks that use the MAC protocol were also examined.

VII. (Vi) Detailing a plethora of future advancements in relation to inspiration and outstanding issues.

EVALUATION OF VOID AVOIDANCE ROUTING PROTOCOL IN UASNs

2.1 Introduction

Based on the publications that were examined and referenced in the research, such as Springer, IEEE, Elsevier, ACM, Wiley, and Smith & Taylor, we considered the distribution of research publications across time. The usage of electronic databases such as Science Direct and IEEE Xplore is also prevalent.

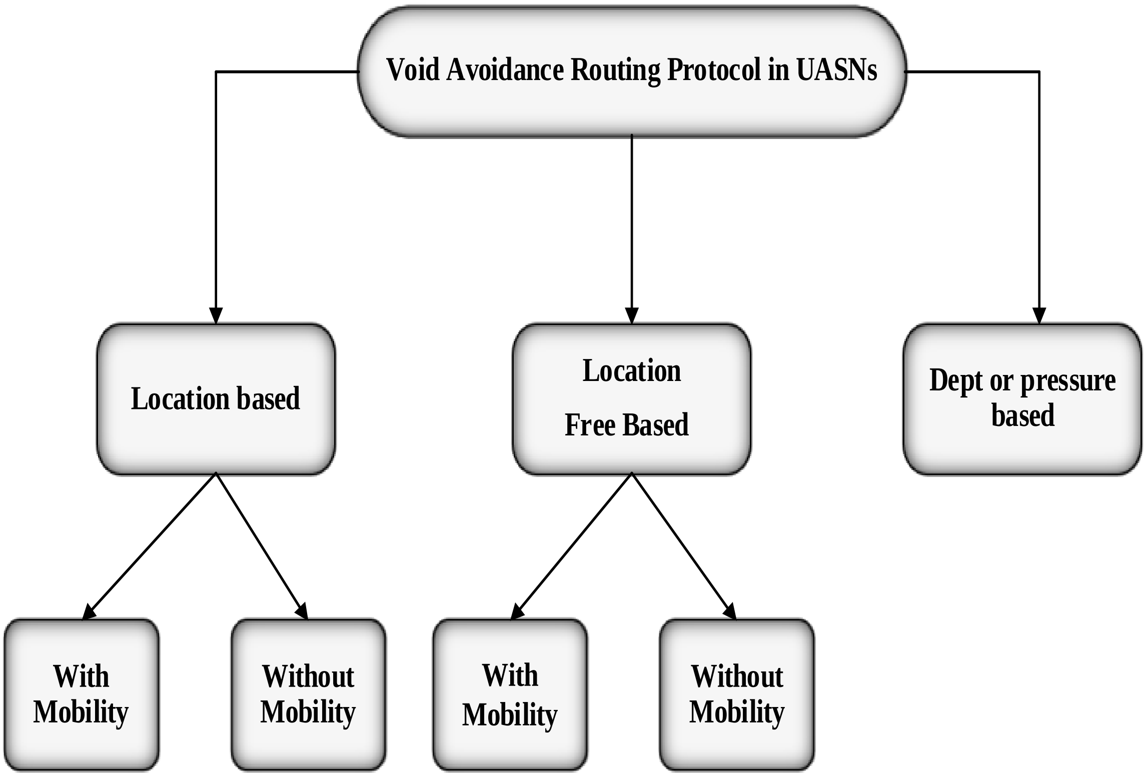

Fig. 2.1 Classification of Void Avoidance Routing Protocol

2.1.1 Underwater acoustic sensor networks (UASN)

When it comes to communicating with people on land, electromagnetic communications are the way to go because they are more efficient, have shorter latency, larger bandwidth, and minimal signal attenuation [15]. While communicating with on-shore facilities, those

Sinks use the radio mode. However, radiological transmission is not possible in water due to the substantial conductivity attenuation that results in significant absorption. Consequently, gearbox range is somewhat limited in water. All of the following are necessary conditions for optical interaction: good perception, a straight line between the receiving and transmitting nodes, and so on. The fast currents and rough waves make these two requirements impossible to fulfil. Hence, beyond a certain distance, visual communication is unable to achieve higher levels of information transfer. Because of these limitations, the acoustical contact mode is commonly used in underwater networks. However, the undersea network cannot directly implement solutions for surface networks' data processing and distribution because of its intrinsic restrictions.

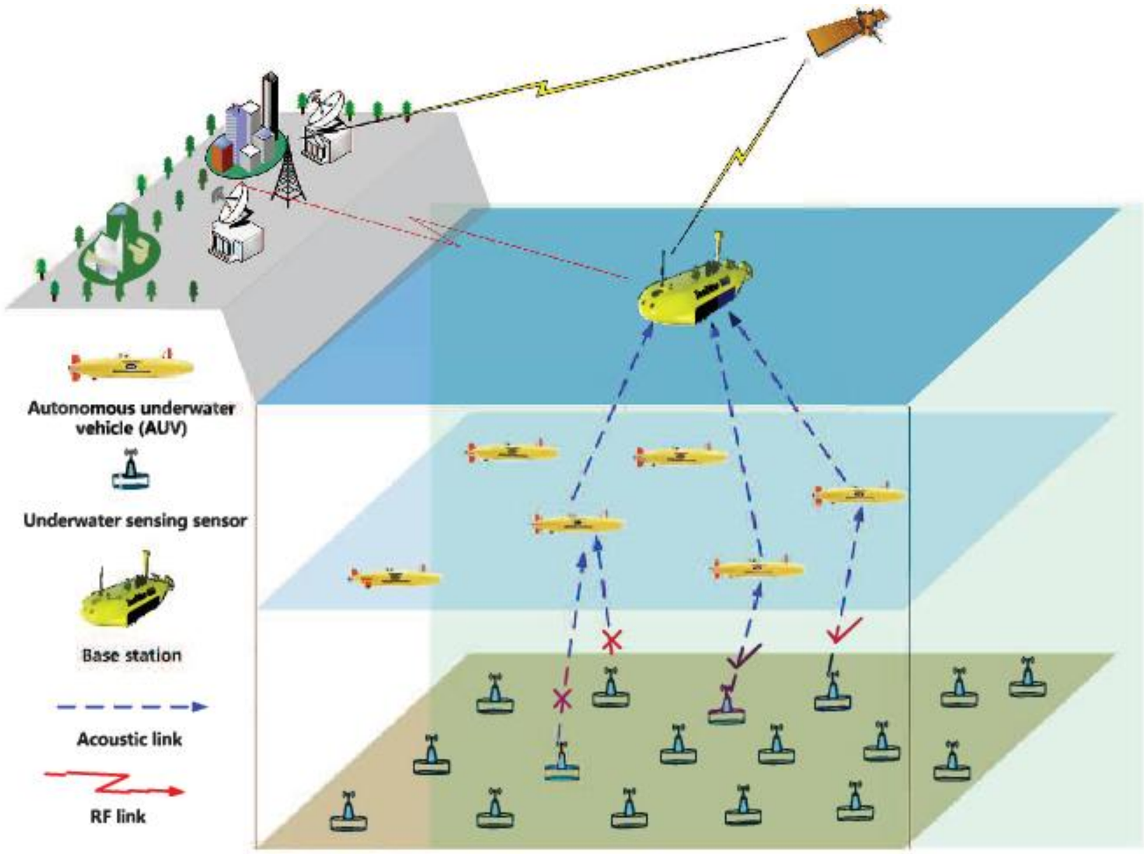

Fig. 2.2 Underwater acoustic sensor networks

Using an audio signal is the only viable way to show the job properly in an underwater environment. While there may be alternative possibilities, such as electromagnetic waves and optical waves in the water, the specifics of underwater sensors still take precedence. The communication range of high-frequency electromagnetic waves is limited to 1 metre in fresh water because of the absorption effect and significant attenuation [16]. Although propagation is tolerable at low frequencies, it isn't without its flaws, such as the high transmission power cost and the need for extraordinarily long antennas. Despite unreliable technical specifics, underwater electro-magnetic modems have made rapid advancements in recent years.

2.1.2. Basics of acoustic communication

Underwater communication has been a focus of research ever since the United States tried to develop an underwater telephony system for submarine communication during WWII [17]. It wasn't until the last 20 years that acoustic communication became the de facto standard for underwater environment monitoring, data collecting, and adventure travel. The most common physical media that allows reliable node-to-node communication in underwater applications is auditory communication. Wireless signals can be transmitted underwater using methods other than acoustic waves. The use of electromagnetic (EM) waves also allows for the wireless transmission of signals under the sea. No matter how salty or fresh the water is, electromagnetic waves in the 2.4 GHz band are highly attenuated. Attenuation measurements for saltwater at 4 mhos/meter and freshwater at 0.05 mhos/meter were found to be 1695 dB/meter and 189 dB/meter, respectively [18]. Attenuation as a function of electromagnetic wave frequency is studied by Lanbo et al. The rate of reduction in seawater increases exponentially with frequency, according to the research. This attenuation makes wireless communication underwater impractical. As a result, electromagnetic waves need to function in lower frequency bands (30 - 300 Hz). However, this can only be achieved with extremely precise seawater conditions, a robust transmission, and massive transducer antennas. Optical radiation is another way that wireless data can be transmitted. Unlike electromagnetic waves, optical waves provide an extremely high data rate. The problem is that water absorbs and scatters optical communications at the same rate, therefore they can't be used underwater. Many pathways, route loss, distortion dispersion, higher and more unpredictable distribution latency, and noise are the primary challenges that develop in underwater audio communications. All of these characteristics impact the geographical and acoustic bandwidth of the channel, which limits the UW-The performance and utility of a channel are very frequency and wavelength dependent. In contrast to a kilohertz system with a range of several tens of kilometres, a system with a range of just a few hundred meters would have a bandwidth of just a few kilohertz. In both circumstances, the considerations discussed before affect bit rates. Worse yet, compared to that terrestrial radio channel, the communication distance is significantly shorter. Long, medium, and short are the lengths of the different types of underwater acoustic communication cables [19]. There was a general vertical/horizontal division of acoustic links based on the sound instruction beam as well. In this example, we see how their propagation characteristics differ in every way imaginable, with a focus on latency volatility, multi-path distributions, and temporal propagation.

One of the most prevalent forms of communication in underwater wireless sensor networks is aural transmission. The following are some of the features of auditory communication:

1. Propagation: When they come into contact with water, acoustic waves behave differently from electromagnetic waves, which move through air or a vacuum. Underwater auditory communication is impacted by a variety of propagation properties, such as attenuation, scattering, refraction, and reflection.
2. Frequency: Waves of sound between 10 hertz and 1 megahertz are used in acoustic communication. Factors including the intended data rate, the type of underwater environment, and the distance between the connecting nodes determine the frequency choice.
3. Bandwidth: Typically, the available bandwidth for underwater audio communication is limited, ranging from a few kilohertz to a few tens of kilohertz. This frequency range is far more limited for radio transmission than the air.
4. Data rate: Due to the restricted bandwidth available, the data rate in acoustic communication is usually significantly lower than in radio communication. Methods like spread spectrum, modulation, and coding can increase the data rate.
5. Doppler shift: Doppler shift happens when the relative positions of the transmitter and receiver change. Transmission accuracy may be compromised due to a shift in the acoustic signal's frequency brought about by this process.
6. Multipath propagation: Underwater objects can reflect, distort, and scatter acoustic signals, which can cause them to arrive at multiple copies at the treceiver. The

received signal may be distorted or interfered with due to this phenomenon known as multipath propagation.

7. Ambient noise: Marine life, wind, and human activity are some of the natural and anthropogenic causes of noise in underwater habitats. The effectiveness of acoustic communication devices can be diminished by ambient noise.

In general, there are a number of benefits and drawbacks to acoustic communication for UWSNs, and these features must be carefully considered while developing protocols and systems for acoustic communication.

2.2 Challenges of UASN

The most common form of transmission is acoustic communication. Mechanical waves, or acoustic waves, are used for thermal transfer in deep water despite their long transmission range. [26]. (ranging from several hundred to many thousand meters). The only way to set up long-distance underwater wireless transmission among devices is through underwater communication, which has the most developed underwater communication technology. However, there is a finite amount of bandwidth that may be utilized because amplified sound waves may experience significant attenuation when they traverse water. Nevertheless, numerous problems with the sensor nodes are evident from the following list.

Path Loss

We need to start by thinking about path loss. For acoustic communication, the required packet transfer rate over a given time and distance is frequency dependent. When the total displacement traversed is reduced and the gearbox power is increased, the effect of time delay is mitigated. Reducing bandwidth at total displacement travelled while boosting transmission power may lessen the impact of route loss.

Three-dimensionality and Node Movement

Three-dimensional underwater sensor networks (UASNs) differ from their terrestrial counterparts in that they track the movement of water. The three-dimensional routing path may experience an increase in packet failures due to these perforations. The concealed terminal problem is more severe in 3D UASNs due to the increased number of adjacent nodes in more directions. In addition, the topology is constantly evolving as the node moves. The speed of node is determined by the water velocity, which changes over time.

High and Variable Propagation Delay

The underwater communication system of UASNs uses acoustic waves for sensing. Underwater, the speed of sound is about 1500 meters per second. Consequently, it causes a substantial delay in propagation, which is five orders of magnitude worse than that of radio waves. The sound velocity changes depending on a number of variables, including salinity, temperature, and water depth. Building void-handling solutions at UASNs requires consideration of the propagation latency.

Limited Bandwidth

Because of the properties of acoustic waves and background noise, the acoustic bandwidth in UASNs is severely limited. The accessible acoustic range is impacted by these acoustic wavelengths and transmission bandwidths. Since the frequency spectrum available to undersea devices is limited, the average throughput is unlikely to ever exceed 100 kilobits per second [28].Constraints on the acoustic channels' wavelengths must be carefully considered while developing void managing methods.

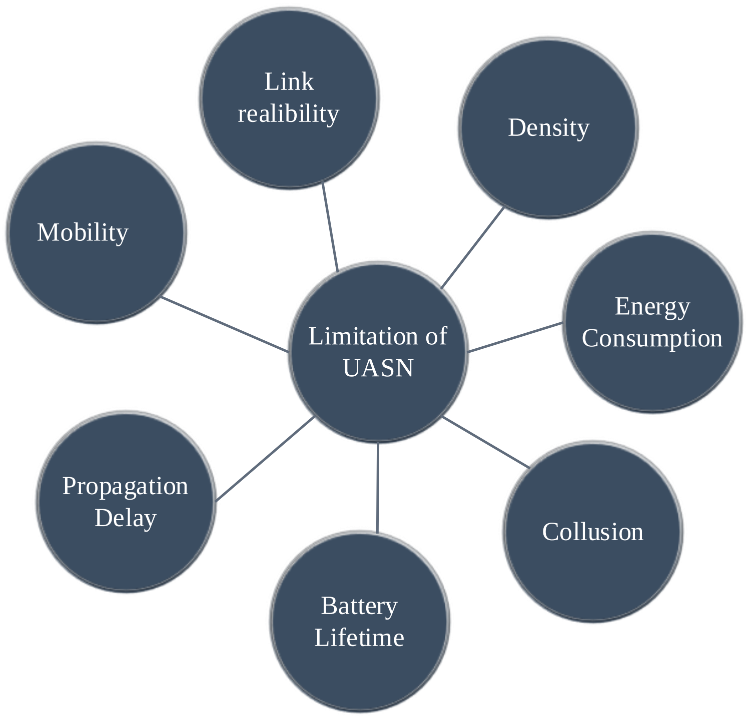

Fig. 2.3 Factors affecting the performance of UWSNs

Energy Consumption

Because UASNs are difficult to repair or even recharge the sensor devices, energy consumption is another big problem with them. Compared to what is employed by ground-based detectors, the force exerted as a result of UASN sensing is significantly higher. Consequently, UASN void-handling systems should be energy efficient at their core. Because of these characteristics, void-handling methods developed for land are totally useless when applied to water.

Noises

Two sorts of noise can affect acoustic communications: ambient noise and noise produced by humans. The majority of the noise that we hear every day comes from human activity, such as pumping water or ships passing by [29].Background noise includes natural events like tides and earthquakes. The primary causes of the noise include shipping, waves, radiant heat, and disturbance.

Multipath:

The following parameter needs to be considered: multipath. We divided communication into two broad types: single-path and multipath. Multipath communication causes a form of signal distortion known as Inter Symbol Interference (ISI), which is the main difference between single and multipath communication. Time scattering is another consideration; while it poses less of an issue for transmission along horizontal channels, it is more of an issue for transmission along vertical lines.

Delay:

Another important factor is delay. Because multi-hop causes packet loss with such a latency parameter, UWSN routing leads to poor communication between nodes. A typical latency for acoustic waves travelling at 1500 m/s is 0.67 s/km[30].

2.2.1 The Impact of Underwater Acoustic Network Protocols on layers

Protocol stack frameworks are becoming more popular as more advanced underwater acoustic communication and networking technologies are developed [31]. Here we will go over this UASN stack:

Physical Layer

Underwater modem research focused on non-coherent FSK modulations until the early 2000s since these approaches don't stage monitoring, which is tough. High-data-rate systems and multiuser networks are not suited to non-coherent modulation techniques due to their poor frequency effectiveness and outstanding energy effectiveness. When it comes to long-range devices, parametric modulating is all about high-throughput. Completely coherent modulation methods, such as PSK and QAM, have only now become feasible due to advanced digital processing. Horizontal underwater channels, especially in shallow water, are severely limited in their usefulness by the time-variability of the channel. Two problems are raised by the multi-path phenomena. The receiving sides are the first to experience ISI, also known as delay spread.

As an alternative, you might look at the transmitter's phase difference spectrum. The joint effects of multi-path dispersion and many-times varying Doppler make high-speed phase coherent communications difficult.

Data Ling Layer

To address the requirements of the data connection layer in a maritime context, we provide a variety of access techniques in UW-ASNs and emphasise outstanding research problems in this section. Substantial obstacles to preventing UW-ASN channel allocation arise from the underwater channel's unusual properties, such as its low bandwidth in relation to its height and its unexpectedly lengthy latency. We do not suggest FDMA because of the devices' low range, UW-ASNs' susceptibility to multipathing and fading interference, and the small bandwidth of the UW-A channels. Since the UW-A channel requires lengthy guards, Time Division Multiple Access demonstrates how bandwidth efficiency is reduced. Longer time guards must be constructed in order to lessen the possibility of packet collisions that come at around the same time. Because of the underwater canal and the considerable communication delays caused by it, these time guards must take Section 4 into consideration. In addition, unanticipated delay makes it exceedingly difficult to achieve the precise synchronisation required by TDMA with a shared time reference. Carrier sense multiple access (CSMA) is used to ensure that users do not disrupt the sender's continuing communications. Avoiding collisions at the receiver end requires setting a guard interval between broadcasts that is at least as large as the maximum network latency of the channel. Because of this, UW-ASNs are not responding favourably to therapy. They use handshake methods like RTS/CTS for dispersed media connect (e.g., MACA, IEEE 802.11) to circumvent the challenges of developing central argument systems for usage underwater. It is difficult to anticipate when other stations will start and stop communicating due to the extreme unpredictability of handshaking packet delays. There is a large propagation delay for control packets as well. While a communication is in progress, using carrier sensing (as in 802.11) makes it more likely that a channel will be recognised as idle; RTS/CTS causes large propagation latency and poor performance at UW-A networks; and UW-A television has poor throughput due to increased diffusion delays. This greatly raises the possibility of an accident.

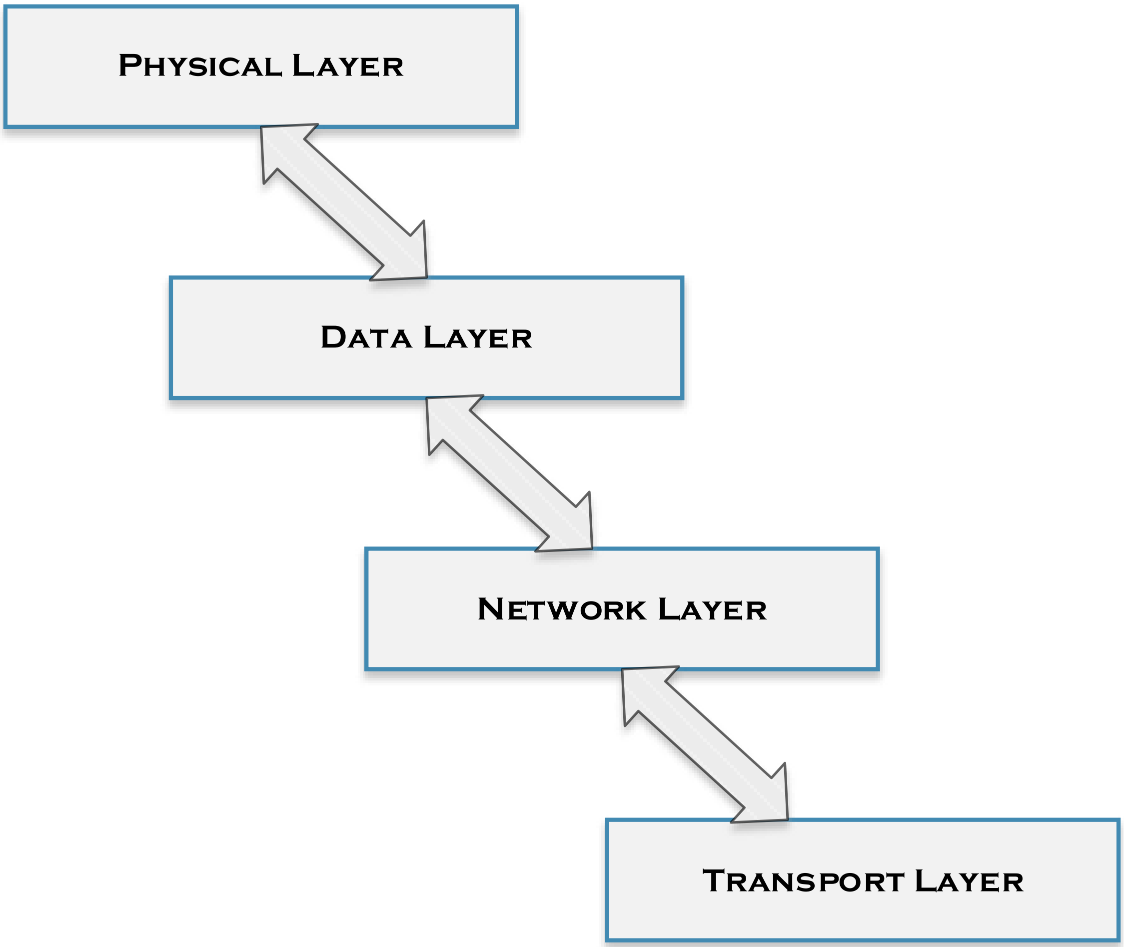

Fig. 2.4 Protocol Stocks

Layers of Neywork

The route from origin to destination is determined by the network layer. The majority of issues with underwater acoustic channels may be attributed to the information and physiological connection levels; however, a more encouraging way to address latency is via the extended internet layer. The number 32.

Much research has focused on protocols for sensor networks and ad hoc wireless routing as of late. Because of their specific use and location in the water, underwater acoustic networks pose new problems for conventional methods. Currently, this function makes use of proactive, reactive, and geographical variables.

Proactive protocols (e.g., DSDV, OLSR),

To reduce the effect of route discovery on message latency, many methods guarantee that the routing information of each node is maintained current. Here, the data from the routing protocol is used to do this. For example, when a network's basic configuration changes due to mobility or node failures, there is a great deal of signalling overhead when these protocols are first employed to construct pathways. This is because updating the topology requires communication between every node. In a UW-ASN, every single node may communicate with every single other node. It is not possible for underwater networks to use proactive protocols.

Reactive protocols (e.g., AODV, DSR), The node initiates the path discovery process only when it finds a route that links to a certain location that is required. A route maintenance mechanism ensures that an established route is maintained until it is no longer needed[33].

In spite of their greater lag and requirement for packet transmission beginning locations in a flood build route, these protocols excel in dynamic environments. Both proactive and reactive protocols rely heavily on flooding, which causes them to have high levels of signaling from above. Due to the slow propagation of acoustic signals in the underwater channel, reactive procedures are believed to be unsuitable for UW-ASNs since they increase delay. In addition, short-term dynamic changes in the topology of UW-ASNs are highly improbable.

Geographical Routing Protocols (e.g. GPSR, PTKF)

The localization detail that many procedures use to construct sources and destinations is dependent on the jumps that follow and the target unit's immediate neighbours. Despite the fact that these methods show a lot of promise, it is still not obvious whether accurate statistics on localization may be obtained in a low-power underwater environment [34].

Consequently, mechanisms for routing data must be developed that simultaneously lessen signalling overhead and latency. While packet switching is the foundation of most ad hoc network protocols, UW-ASN could make use of virtual circuit routing algorithms anyway. In such systems, the pathways between each source and sink are predetermined, so every packet follows the identical route. More efficient pathways may emerge from this, but it may also necessitate a centralised coordination mechanism.

In addition, while designing routing algorithms, 3D underwater surroundings need to be considered. It is important to take currents into account, especially in a three-dimensional situation, since the direction and strength of the present information are dependent on the position of the sensing data type. Therefore, ocean currents can change the relative locations of sensor equipment and cause communication gaps when monitoring the ocean column in deep seas.

Transport layer

Details on the transport layer of UW-ASNs are unknown at this time. In this article, we will go over the basics of creating a trustworthy transport layer protocol that satisfies UW-ASN standards. A few dependable ways for data transport across submerged wireless sensor networks are also covered [35].

Sensing networking and accurate activity identification at the sink require combining data provided by the destination node; relying on a single report from any source is not an option. Because of this, traditional end-to-end dependability methodologies and descriptions could not be applicable to underwater sensors, which might result in the loss of useful sensor materials. However, it may be impossible to notice occurrences because to the difficulty of obtaining dependable transportation underwater. Hence, the UW-ASN paradigm calls for a whole new concept of event transit dependability, as opposed to his conventional end-to-end methods.

For UWASNs to regulate flows and control congestion, as well as provide reliable collective transfer of incident aspects, the network layer protocol must be in place. Conserving limited sensor resources and optimising network effectiveness are the primary objectives. Application accuracy in recognising event features computed by a sensor network depends on a reliable transmission channel. Network devices with limited memory can be overwhelmed by data transmissions meant for UANs, which is why flow management is essential. On the other hand, control schemes are needed to keep networks from being clogged due to excessive data relative to the overall capacity of the connection.

2.2.2 Importance of Geographical Routing Protocols

A number of convenience and security applications call for enhanced communication and routing protocols in the network. To keep delivering routing services in the network, all routing strategies must have optimal road-aware routing metrics. The protocols that fall under the umbrella of geographical routing protocols are the most suitable for dealing with highly mobile users and topologies that are constantly changing [36].

Position data is crucial for geographic routing algorithms, particularly those developed for real-time applications. The network is troubled by disconnections brought on by heavy mobility. Routing techniques should include a direction metric and a loop-free strategy to circumvent this problem. The majority of researchers have said that they would concentrate on routing, localisation, service quality, security, broadcast storms, and local maximum/minimum in their study. To manage highly mobile nodes and changing topologies, geographic routing approaches provide their own set of routing metrics. Figure 2 lays out the primary criteria for geographic routing methods. An effective method for organising routes and fast packet transmission to lower network overhead are the two main requirements for routing. There is less overhead and higher efficiency in the network because of these criteria [37]. Prompt, error-free location data provided by protocols is the only way to address the issue of frequent disconnections. Incorrect forwarding choices will be prevented by this. To lessen the effect of latency on networks, protocols include a load balancing approach. These oceanic features contribute to transmission's high energy consumption, high error and delay rates, transient connection drops, restricted bandwidth, and high cost

Since UWSNs communicate via sound waves, simple application of typical TWSN algorithms to them reduces system achievements. To address this issue and enhance communication in underwater networks, several protocols have been developed. These issues provide a number of challenges when formulating protocols for underwater routing and sensing [38].Improving UASN performance with routing algorithms is also a major focus of researchers.

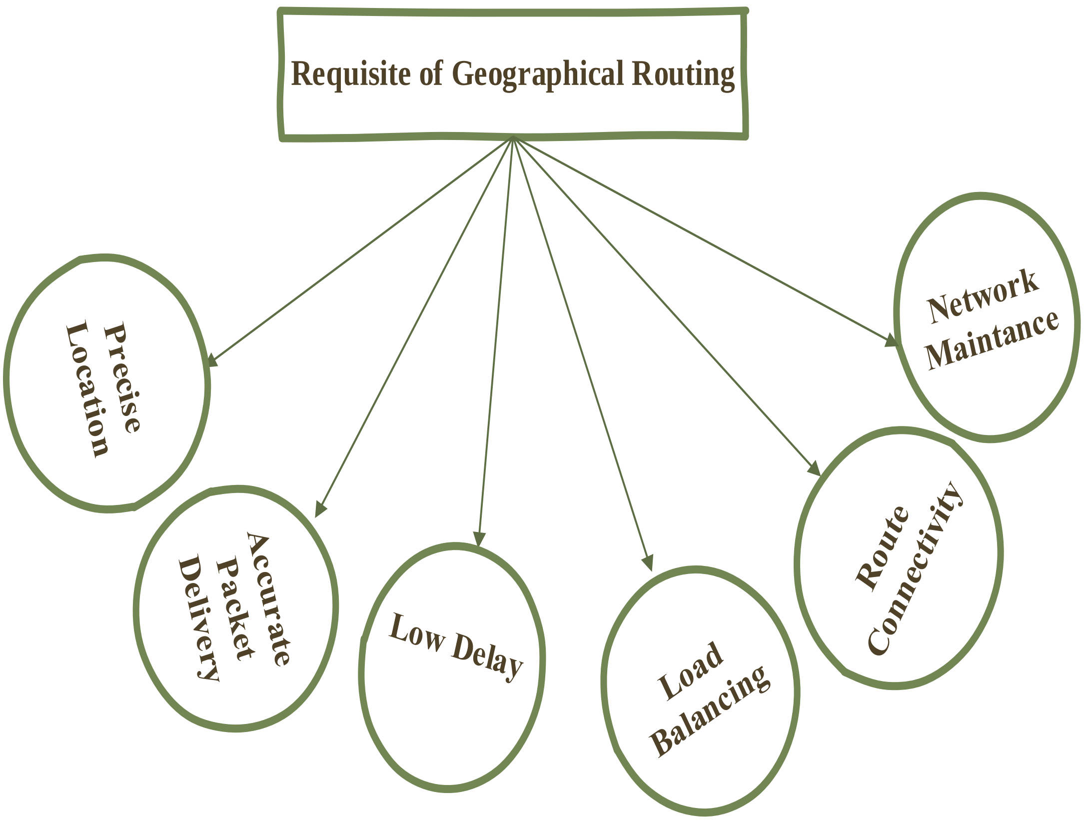

Fig. 2.5 Requirement of Geographical Routing

Routing ensures the smooth transfer of data from its point of origin to its final destination. There is a severe lack of processing power, storage space, and network connectivity among underwater sensor nodes. Conventional terrestrial routing methods' strong propagation, community-level uplink, and power consumption delay make them ill-suited to UWSNs. In addition to having a smaller focus, UWSN routing protocols are also technologically superior. In challenging underwater environments, the underwater routing protocol ensures that network communication routes are reliable and effective. Scalable underwater routing methods allow for changes to the network's structure and stability to be accomplished [39].

One typical use for routing algorithms is the transfer of data to and from underwater interfacial connections and their appropriate destinations. Among the many available routing algorithms for UWSNs, greedy routing protocols stand out for their ability to maximise packet delivery while reducing energy and delay costs. One potential approach in localization-based sensor and ad hoc networks is spatially greedy routing. "Geographic greedy routing" is a theory of network routing that uses geographic location data to gradually bring packets closer to the destination with each hop. Unlike table-driven routing, which uses the shortest path between two points to construct end-to-end routes with high connection costs, geographic routing takes into account more than just this one detail. For the most part, packet routing on both one- and two-hop protocols has relied on these same geographical data. It follows that the networking tables and alerts are superfluous for storing and updating the route path. Because of their one-of-a-kind feature, they can be easily scaled to accommodate networks with many nodes. Because it decreases the delivery of control packets, geographic forwarding is a commonly utilized routing approach in UASNs [40]. Recent routing schemes' extensive use of position-based greedy forwarding has made this problem much more severe. Geocast is an additional capability of geographic routing that allows you to target a specified location to receive a packet. An approach known as greedy-forwarding is used in geographic routing. In this method, each node searches for its neighbours that is geographically nearest to the ultimate destination. It is unfortunate that communication problems or the local maximum phenomena might lead greedy forwarding to fail. Even if the packet's path from origin to destination is perfectly clear, it can still be lost in transit if the node responsible for forwarding it couldn't locate any suitable nodes, even ones with promising future developments in the direction of its final destination.

VOID AVOIDANCE ROUTING PROTOCOLS

3.1 Introduction

Enhanced network performance, reduced energy usage, and data packet delivery in the face of underwater obstacles are all achieved through the use of these protocols, which dynamically modify paths in response to void detection. Several considerations, including node mobility, energy limits, and environmental conditions, must be carefully considered in order to implement VARPs properly.

Creating a network architecture and tracing the connections between nodes using their locations is a typical method. Underwater wireless sensor networks rely on position-based routing protocols like PBR and D-PBR to overcome obstacles like voids and guarantee efficient data delivery. By using the positions of nodes to build a map of the network, these protocols may determine the shortest paths between them, avoiding empty spaces along the way.

Another strategy involves utilising depth information to steer clear of gaps created by underwater features like canyons and mountains. Modified Depth-based Routing Protocol (MDRP) and Depth-based Routing Protocol (DBRP) are two protocols that employ depth information to find a route that avoids these obstacles and ensures reliable connection.

Finally, certain VARPs respond to changes in the network's architecture brought about by node moves by utilising mobility information. Protocols like as Mobility-based Routing Protocol (MBRP) and Adaptive Location-based Routing Protocol (ALBRP) take advantage of nodes' ability to move around in order to constantly refine the network's topology and find the best route between them.

Void avoidance routing techniques are frequently necessary for dependable and efficient data transmission in UWSNs, which typically have complicated communication mediums and network topologies that can vary due to external influences.

3.2 Importance of Void Avoidance protocols

Geographic routing can't be used in next-gen wireless networks until it solves the challenging problem of communications vacuum. A dense distribution of wireless nodes will reduce the likelihood of a vacuum forming in the network. However, voids can still be caused by barriers, malfunctioning nodes, wireless network borders, and similar circumstances.

These packets must be deleted while using a single greedy-forwarding technique, even if there is a topologically valid path to the target node. For geographic routing to work, a void-handling method must be effective and efficient. You can use a distributed neighbourhood table on the node itself [41] or you can leverage a dispute between nearby nodes [42] to find out where your neighbours are. The source node's transmitted packet header includes the destination's location. An intermediate node may decide to change the position in the packet header before sending the packet onwards if it has a better idea of the destination's exact location.

The greedy-forwarding approach determines the optimisation criterion that is used to choose the next-hop node [43]. Senders go into void-handling mode when they need to transmit data packets but can't find a node that's currently going in the same direction. This mode allows the node to get a better sense of the destination's location by attempting to route the packet around the void.

The aforementioned study identifies the difficulty to periodically recharge the sensor nodes as a major downside of UASNs. If the power goes off quickly, the sensor nodes won't be able to send any more data. The UASN also takes mobility into account when collecting data.The majority of the proposed routing algorithms for UASNs completely fail to tackle this issue. The safety of data transit is another major issue with UASNs. Sensor nodes collect and store sensitive data in many industrial and military applications. It is crucial that this sensitive data is transported safely to the sink nodes; otherwise, there is a significant risk of harm. It has also been found that there are several communication gaps in marine environments. Message gaps occur when a sending node can't find a receiving node that is both in its transmission range and facing the right way to the destination. These problems are sometimes known as communication voids, communication gaps, or the unreachability dilemma. Multiple circumstances can lead to the formation of network gaps. These include intermediate nodes failing as a result of energy depletion, incorrect deployment, intrusions, attacks, etc. One of the primary goals of developing a routing protocol for UASNs should be to bridge the communication gap that occurs during routing. Node lifetimes are reduced, packet dropouts are increased, and delays in packet delivery to the sink are accelerated in UASNs when void and trap nodes are present during packet routing [44]. When designing void control solutions, it is important to take into account the noisy and lossy underwater environment that these sounds produce. As a result, void-handling algorithms that try to account for every possible attribute must be developed in order to facilitate underground acoustical telecommunications. When a ship navigates across an underwater network, it can disrupt local communications and leave a vacuum behind it.

It is often more challenging for properties that use underwater sensor networks to operate in three-dimensional, movable voids. As a result, well-designed void-handling algorithms are essential for UWSN routing protocols. The amount of void nodes, network dynamics, and destination count are only a few of the many variables that affect how well certain void-handling strategies function. Here, we take a close look at each of the potential routing systems for this study. Two categories of protocols have been established according to the degree of localisation required: optimization-based schemes and depth-based schemes. The localization-based classifications that take sensor node flexibility into consideration and those that do not are vastly different.

3.3 Depth based void avoidance routing protocol

The candidate list is produced and prioritised by pressure-based opportunistic routing protocols using depth and water pressure data near the sensor nodes that are situated at different depths of the ocean. Due to the fact that different heights produce different water pressures in the ocean, it is possible to employ a sensor module to locally determine the depth of each node [45]. The idea behind pressure-based routing is to use a low-cost pressure sensor embedded in the sensors to locally detect the node depth. To rephrase, packet forwarding can be performed by any one-hop neighbour node that is deeper than the sender node and located in the zone of positive changes towards sinks. In order to choose which forwarding node to use in order to avoid the void, an energy-efficient optimal path routing algorithm was developed for use in underwater acoustic sensor networks [46]. This method for removing the networks followed the deep differential approach and relied on residual and signal strength. The Grey Wolf Optimisation was used to pick the best forward node to avoid the void by integrating fitness value with the DBR principle. Consequently, energy equity extends the life of the network by distributing the expenses of data transmission across density knots that are properly distributed. Matlab was utilised to model the effects of decreasing energy consumption and packet delivery failure on a network's lifespan. The presence of vacant zones is the greatest obstacle to the routing protocol of an underwater sensor network. It is possible that the void will cause data loss when transferring data from one sink node to another. The routing hole impacts the network's longevity, propagation delay, and energy consumption. Therefore, an Underwater Acoustic Sensor Networks—an energy-efficient routing option—is shown by this network. Efficient and void-avoidance routing based on the grey wolf optimization method is discussed in [47]. Taking into account the depth difference, the angle between the depth and the direction of propagation, the energy and efficiency of nodes, and the excessive depth difference of many surrounding nodes, the GWO technique selects the best forwarder node, improving the efficiency of depth-based routing protocols. According to our findings, using the optimal forwarder node improves the primary assessment metrics: average energy, thickness difference, and connection strength. Considering the narrower angle shortens the transmission and decreases the likelihood of communication errors. The GWO algorithm modifies the channel's lifetime and verifies the transmission delay.

Edove: Underwater acoustic sensor networks were used to examine proactive void avoidance methods that rely on resource and thickness variability. Data packets are sent to the sink based on the depth of transmission of the node-based model's forwarding mechanism. Nodes depth parameter and remaining energy were taken into account in [48], which completely eliminated the void region. The nodes' holding durations were calculated using the discrepancies between the forwarder connectors and the residual power. In addition to maintaining energy equilibrium, this tactic prevents you from reaching the empty zone. It also helps with energy balancing, which is important for avoiding the empty space. Because of this, it helps the network last longer.

The reason why depth-based routing is gaining so much attention is that it has the potential to work well even without full-dimensional sensor location data.. In [49], the authors propose a Distance-Vector based Opportunistic Routing for Underwater Acoustic Sensor Networks as a solution to these problems. In order to determine distance vectors, DVOR uses the underwater acoustic nodes that count the fewest hops towards the sink. Next, opportunistic routing based on distance vectors is used to coordinate the packet forwarding. By taking use of opportunistic forwarding, DVOR might potentially avoid problems with empty areas and long detours while having a minimal signaling overhead.

Table 3.1 Comparative analysis of depth based void avoidance routing protocols

Author	Depth based Protocol	Detecting forwarding node	Delay	Packet delivery	Energy Efficiency	Path Optimality
Singh.et.al [46]	The Efficient Optimal Path Routing (EEOPR)	Yes	Yes	Yes	Yes	Yes
Gola.et.al [47]	Grey Wolf Optimization Algorithm	Yes	No	No	Yes	Yes
Bouk.et.al [48]	The energy and depth variance-based opportunistic void avoidance scheme	Yes	Yes	No	Yes	No
Guan.et.al [49]	The Opportunistic Routing based on Distance-Vector	Yes	No	Yes	Yes	No
Yu.et.al [50]	WDFADDBR: Weighting depth and forwarding area division	Yes	No	Yes	Yes	No

	DBR routing protocol					

Weighted forwarding area and depth WDFADDBR classification. The WDFAD-DBR routing protocol, which stands for weighted depth and forwarding area division DBR, was first proposed in [50].

The likelihood of encountering vacuum regions is so reduced. To reduce energy waste caused by duplicate packets and neighbours requests, the forwarding area division system and the neighbours node prediction method are designed accordingly. In the third place, we evaluate the theoretical efficacy of routing in terms of average end-to-end delay, capacity utilization, distribution proportion, and channel competitiveness. Finally, we extensively simulate WDFAD-DBR using the NS-3 simulator to validate its efficacy and validity.

3.4 Location-Based Routing Schemes

In this section, we examine all of the routing protocols included in this research. Depending on whether of these two criteria is satisfied, we may say that the protocols are either localization-based or localization-free. Then, we may further subdivide these groups based on whether the protocol limits or allows the sensor nodes' movement. Additionally, continuing research is being conducted about the possible applications of UW-ASNs, which stand for underwater acoustic sensor networks. Some of the issues that arise with these networks are acoustic channels, bandwidth, variable propagation delays, and node mobility. To choose the best data transmission cable, one must make informed assumptions about the locations of the sensor nodes (see to Table 1).

3.4.1 Routing based on Location with Mobility

Using a reinforcement model for pack forwarding, the authors of [51] propose an adaptive Q-learning strategy for managing the auditory environment. In order to get data to the last node as quickly as possible, the technique chooses the optimal path. The data is distributed evenly across the nodes to guarantee use of little energy. Conversely, the suggested model's local optimal choices increase the probability of network holes.

This study introduced the Cluster-Based Adaptive Routing Algorithm in [52] to address the requirements of underwater acoustic sensor networks operating on a large scale. In an effort to streamline the network design, the concept of a grouping for cellular wireless communication was proposed. Master the art of concentration with the help of frame-based and hop-by-hop models of network dynamics. The CBAR method should perform better with large-scale UASNs due to its foundation in the Routing protocol. By sending and processing data packets in groups, the gap may be avoided. In order to account for the specifics of the maritime environment and to regulate power consumption during routing, CBAR incorporates two kind of adaptation updates. Data packet delivery formats are simplified in a clustered network. Power regulation and adaptive technique adjustments in real time may reduce the effect of a moving body of water. The models' findings show that the methods may drastically cut down on the transmission energy usage of the network.

Hence, as mentioned in [53], these qualities must be included in the UASN routing algorithms in order to achieve energy balance, reduce void holes, and extend the life of the network. This paper presents an energy-efficient optimum path routing that may be utilised in underwater sound sensor networks to avoid the vacancy node. The top forwarder node can be selected utilising the black widow optimisation technique after the optimisation technique has been calculated. One may do far more in much less time by focussing only on the vertical plane. Use of MATLAB for the stimulation of proposed work has been evaluated based on a number of criteria, including the percentage of packets delivered successfully to the total network lifespan, energy consumption, number of dead nodes, and duration of the simulation.This study suggests that DVOR could be a solution to the problems with DBR's void region by redirecting forwarding traffic [54]. For distance vector computation, DVOR makes use of submerged acoustic nodes that incur the fewest hops towards the source. Once the distance between each pair of nodes has been determined, the query approach is used to route the packets individually along the most favourable shortest path to the destination. Coordination of packet transport requires opportunistic routing based on distance vectors.

Because DVOR takes very little additional time for signalling, opportunistic forwarding allows you to avoid spending time flying over empty regions or taking unnecessary lengthy routes. For received packets, DVOR outperforms competing algorithms in simulations with respect to forwardingrate, energy economy, and latency.

An abbreviation for "depth-based routing with subdivision by weighted depth and forwarding area," "depth-based routing" takes into account the source node's first-hop and second-hop neighbours. A technique for packet forwarding from forwarding nodes is proposed by the BDREA protocol; this might be of value to betta fish and dolphin communities. Considerations such as network traffic, packet distance from the central station, and energies of the inverse normalised advancing area are taken into consideration by this technique. This approach may increase network lifetime by 50% and energy efficiency by 30% according to the Dolphin and Whale Pod (DOW-PR).

The incredible mobility, minimal bandwidth needs, and zero latency of UASNs make them an essential component of the technology that enables the Internet of Things (IoT). The challenge of developing reliable routing systems is heightened by these issues. An ALRP is suggested for use with 3D UASNs to circumvent these problems. A forwarding region is created by ALRP so that forwarders can be regulated. Using adaptive forwarding probability helps cut down on unwanted transmissions. The forwarding order is established using an adaptive method that takes transmission delays into consideration. Then, based on a variety of performance metrics, ALRP will choose the optimal relays to route packets. The VBF may fail to detect forwarding nodes in sparse networks due to the existence of void holes. Significant delays can be caused by network deficiencies.By implementing cooperative routing and energy-efficient clustering based on upgraded K-means and Q-learning, it was suggested that the amount of energy consumed by mobile UASN detector modules may be decreased and distributed more fairly.

Using parameters such as cluster-to-cluster distance and residual node energy, the ECRKQ can modify the K-means algorithm to select a CH. When clustering, ECRKQ takes into consideration the Q-value function to account for power consumption at every stage: the power remaining in the CH, the power used by the node when transmitting data to the CH, and the power used by the CH when transmitting data to the network device. During DCC transmission, the ratio of available to necessary energy for packet transport determines which cooperative nodes are chosen dynamically. In order to replicate the movement of nodes, we use a mobile simulation that is based on a drifting model of ocean currents.

The UASN AREP [58] offers a solution to the problem of an imbalance in oceanic senders and receivers by facilitating two-way communication. Discovering the state of links, planning the best routes, filling in gaps, and updating routes are the four steps that make up the protocol. A node constructs its neighbour tables during its first boot. In order to find out how symmetrical a node is in relation to its neighbours, link state identification makes use of tabular data. After then, potential relays are chosen from among all the connections that have a two-way relationship with that sender. It chooses a possible forwarder according to how close it is to the receiving node. To apply, the forwarder applicant needs to make the least amount of trip. Rearranging nodes alters the topology of the network, which calls for additional connections. A node's neighbour databases will be updated by nodes upstream to reflect the new connectivity when it is moved and starts linking to other nodes. The delivery rate can be increased using AREP by meticulously choosing relays. It can jump to other network topologies with ease and is quite portable. Maintaining a well-oiled table requires constant small conversation. DQELR [59] takes cluster quality of service into account. Its goal is to provide the least latency and quality of service requirements while reducing modifications to underwater channels. This is achieved via DQELR by use of a micro-clustering technique, wherein sensor nodes are linked in a hierarchical fashion to more efficiently distribute traffic and power. When deciding on a routing path and how to transmit data, a greedy algorithm is used, which takes into consideration the quality of the linkages between cluster heads. By including quality-of-service into shortest path selection, network latency can be reduced and efficiency can be raised. Additionally, in the event of a forwarding node failure, the transmission power is adjusted using the information from the routing table in order to keep the network operational. But, cluster heads may quickly drain their power supply if they are burdened with an excessive amount of work.

To circumvent voids, scientists developed an algorithm they dubbed Efficient Energy Optimal Path Routing (EEOPR) in [60]. By taking into account the "depth difference of nodes," energy, and connection accuracy, this technique makes an effort to circumvent these issues. The artwork makes use of the striking contrast that exists between the transmitters that are located closer to the viewer and those that are located farther away.

Both the holding time and the residual forwarder energy are measured in line with the standards that are established by the two-hop forwarders. This not only extends the lifetime of the network but also improves energy equity and reduces the cost of data transfer among nodes that in near proximity to one another. EEOPR was discovered to be able to aid in reducing the amount of time it takes for a node to deplete its energy by around 42 seconds, increasing the lifespan of the network by more than 49%, and reducing the number of copies that are required to disseminate data packets by approximately 49%. It was possible to discover the following set of nodes by taking into consideration reach criteria. The inability to locate the node that is geographically nearest to you is a significant barrier to mobility. By using a novel approach to modify the level of information that is exhibited, it attempts to close the gap that exists in terms of communication. On the other hand, neither the MSLETR nor the MSGER retain any esoteric relevance.

It was suggested in [61] (EAVARP) that the energy-aware and void-avoidable steering protocol be used.EAVARP must complete its operation in the underwater acoustic sensor network in two phases before it can be considered complete. The sink node and concentric shells are used upon the initial level, which is referred to as layering. Every sensor node is housed inside of one of the numerous shells that are constructed. In the second phase, which is referred to as the information collection phase? In this particular instance, the data bundles are sent via the use of the Opportunistic Directional Forwarding Strategy. ODFS helps to avoid void, flooding, and cycle movement by monitoring the flow of data and energy between nodes inside the shell. This helps to ensure that the whole system is functioning properly.

EEDC-AA [62] suggested a way to gather data. Data must first be sent from the sensor nodes to the Sinks device, which is the initial stage. In this second section, we will discuss the process of data extraction via the use of information-based AUV route planning. Both the prioritization of reactions to crucial events and the classification of data according to value are also within its capabilities. It is unfortunate that it does not address a significant issue, which is the evaluation of the worth of the information. The proposed method extends the life of the network by reducing the possibility of void generation through the use of load balancing.

MFPR [63] locates energy-efficient underwater sensor nodes via memetic flower pollination (MFP). Two stages will be included. (A) The efficiency of source-to-sink routes is enhanced by MFP. Using the top forwarding nodes in the initial population, a group of relays creates a source-to-destination route. Fitness is the basis for MFP's direction of people. By alternating between global and local pollination, FPAs ensure that packets are transmitted over trustworthy routes. Latency is decreased in MFPR by GFPDMA. By successfully distributing packets with minimal synchronisation delayed &excellent power efficacy, MFPR improves the lifespan boosts the system throughput and strengthens the connection. Close to the washbasin, MFPR places replaceable nodes to cover any holes in the node dissipation system. As a result, the question off.

Table 3.2 Comparative analysis of existing techniques with mobility

Author	Protocol Name	Contribution	Energy Consumption efficiency	Latency / packet loss	Network Life Time	Disadvantage
Khan, Zahoor Ali, et al. [51]	Q-learning Routing Protocol	It is used to developed balance of energy and detect the avoid hole to enhance the life time of network	High energy efficient is achieved	Moderate	High value is achieved	Packet Delivery ration will be implemented for reduce the latency
Zou.et.al [52]	Cluster-Based Adaptive Routing Algorithm (CBAR)	Transmitting the data through avoiding the void using clustering approach	Moderate level	Not Considered		Further simplification is needed to be enhanced for power consuming Delay

Gola, Kamal Kumar, and Bhumika Gupta .et.al [53]	Black Widow Optimization Algorithm .	Prevent the void hole and achieve the balance energy is aim of this paper	Efficient	Moderate	High	Packet delivery ration will be enhanced
Guan.et.al [54]	Distance-vector-based opportunistic routing	Void avoidance is achieved through packet forwarding	Moderate	Low	Moderate	Energy consumption and network simplicity will be enhanced
Zradgui. Et.al [55]	BDREA Betta and Dolphin Pods Routing	Packet forwarding with avoid the void the hole	Moderate	Low	Considered	Forward packet delivery is considered but energy consumption will be concentrate
Wang.et.al [56]	adaptive-location-based routing protocol	Purpose for finding the forwarding node probability	Low	Low	Moderate	Low bandwidth is issue
Zhu.et.al [57]	Machine Learning-Based Energy-Efficient Clustering and Cooperative Routing	Energy based clustering scheme is presented for sending packets	High	Low	Moderate	Forwarding nodes and void nodes finding will be implemented

Han.et.al [58]	asymmetric link-based reverse routing (AREP)	The routing void problem is addressed in AREP through eliminating void nodes.	Moderate	Low	Moderate	Bandwidth and complexity
Su.et.al [59]	energy- and latency-aware routing protocol based on adaptive deep Q-network	To achieve the prolong life of network	High	Low	High	Forwarding node through avoiding void detecting will be enhanced
Singh, B. et.al [60]	An Efficient Energy Optimal Path Routing (EEOPR)	To avoid the void	Moderate	Moderate	High	Energy consumption, packet depletion is needed to be concentrate
Wang.et.al.[61]	void-avoidable steering convention	Avoid avoidance	Moderate	Moderate	Moderate	Overall performance will be implemented
Jing.et.al [62]	Energy-efficient data collection over AUV-assisted	Promote the lifetime through load balancing approaches for avoiding the void	Moderate	Low	High	Complexity

Sivakumar. et.al [63]	A QoS-aware energy-efficient memetic flower pollination routing protocol	With aim of enhance the QoS	High	Low	High	Delay sensitive application will be incorporate
Ayyadurai, M.et.al [64]	Optimization of data reliability in UASN using adaptive Buffalo algorithm	Optimization of data reliability in UASN	High	Moderate	Moderate	Efficient void avoidance is needed for forwarding the packet
Baba-Ahmed.et.al [65]	Mobility Aware Strategy for Geographical Routing Schemes		Low	Low	Moderate	High energy consumption

The lack of forwarder nodes in the network is the root cause of the inability of nodes to transport data from one node to another. As a result, the routing of underwater acoustic sensors is centred on resolving the problems outlined above in order to extend the lifetime of the networks. The most apparent issues with this gadget are the amount of energy it consumes and the inefficiency of the data transmission that occurs between the sensor nodes that are located underwater and those that are located on land. If you want to fix this problem, the protocols that have been offered include avoiding void gaps and stabilising the connections. A necessary step in achieving optimum performance is the identification of methods that may lower the amount of energy that is used. In order to prevent connection failure caused by congestion, unfavourable environmental conditions, or energy dropout, it is essential to take use of the routing protocol that was developed specifically for use in the ocean. The characteristics of the African buffalo served as the basis for the development of a novel optimisation technique that was referred to as the Buffalo optimisation algorithm (BOA) and was introduced in the year [64]. In UASN, the most common reason for power loss is associated with collisions that occur at the intermediate nodes. When traffic is generated in an unpredictable manner, it also contributes to the establishment of dead nodes at an earlier stage. The BOA makes advantage of multipath communication that is built on lookup tables in order to overcome these barriers. The problem of dead spots, which occurs when a node is unable to locate the next forwarder node, was solved by the people who developed [65]. A method for avoiding empty holes that is based on the adaptive hop by hop vector principle The strategy of forwarding routing serves as the foundation for the protocol. Through the use of two-hop information, the goal is to choose a node that is not vacant in order to avoid data from being transferred to empty spaces. A mobile sink should be installed in an open region, as recommended by the protocol, in order to improve data collection while simultaneously lowering power consumption and packet loss.

3.4.2 Routing based on localization without Mobility

Underwater wireless sensor networks that employ static node placement have proposed location-based routing methods, which are summarised in this section.

In this article, the author [66] talks about how they created and tested a new multi-hop routing scheme for underwater wireless sensor networks. Underwater settings are the target of this protocol. The Channel-aware Routing Protocol (CARP) is our approach that uses connection quality data to forward data. To do this, we use the nodes' track records of successful data transmissions to neighbouring nodes when choosing them as relays. Using fundamental topological characteristics such as the hop total, CARP successfully avoids circular connection gaps and dark areas. On top of that, strong link selection through power control was an additional goal when developing the protocol. CARP is contrasted with a flooding-based method and Focused Beam Routing. When compared to both options, CARP performs better (EFlood).

One cluster-based routing protocol that the author suggests is ACUN [67]. The ACUN system accounts for the distance between washbasins and CHs while creating a node hierarchy. By factoring in the quantity of wasted energy, we may determine the competitive radius of CHs. It takes into consideration the residual energy of the CHs. Leaders in clusters can be centres with a lot of residual energy. A competitive hub (CH) is shielded from harm by the ACUN's extensive protection radius. The proposed approach can prevent the CH from sending a stronger signal when the distance between the CH head and sink node increases. When its expiration time is earlier than the network as a whole, a CH will leave gaps. We must not let ACUN to let that happen. Instead of relying on a single direct link, routing makes use of multiple intermediate stops. Nodes further away from the sink can benefit from multi-hop routing since it allows them to transmit with less power consumption compared to a single hop. Since ACUN consumes less power, a network can last longer. Depending on the distance from the washbasin and the remaining energy, ACUN adaptively changes the CH competition radius. The end-to-end delay is reduced and the packet delivery ratio is increased as a result of this drop in void production. This method necessitates location estimates, which will drive up the cost. Still, mobile nodes aren't given any attention either.

(1) corona-based energy grade and balancing load distribution (2) depth adjustment (DA) are the three routing approaches that make up EGBLOAD, as described by the author [68]. The combination of these methods allows for great energy performance and channel longevity by intelligently distributing the network's traffic load throughout its nodes. Before anything else, the energy stored in this node's battery is graded according to the distance between the sender and the receiver. In order to reduce forwarder congestion, Grade (EG) without energy Corona segments data packets into large, medium, and small portions. The outcome is a more equitable distribution of traffic. Depletion of the corona induces a reduction in network voids. Modifications to the forwarder's depth have no effect on its connection with its neighbours. By carefully choosing forwarders while factoring in residual energy, the suggested method also ensures balanced load distribution.

Table.3.3 Localization-Non -Mobility Based Void Avoidance Protocol

Author	Protocol Name	Contribution	Energy Consumption efficiency	Latency/ packet loss	Network Life Time	Disadvantage
Basagniet al. [66]	A channel-aware routing protocol	It is used to developed balance of energy and detect the avoid hole to enhance the life time of network	High energy efficient is achieved	Considered	High value is achieved	Packet Delivery ration will be implemented for reduce the latency
Manel.et.al [67]	ACUN, which is a cluster-based routing protocol	Void avoidance achieved through load balancing	Low	Moderate	Low	Overall performance will be implemented
Rekha.et.al [68]	corona-based energy grade (EG) & balance load distribution or EGBLOAD	Void avoidance achieved without mobility	High	Low	Moderate	Dead Cell prediction will be enhanced

3.5 Localization free Void Avoidance Techniques in UASN with and without mobility

However, contrary to what the name indicates, localization-free routing algorithms do not make use of the locations of nodes in order to select transmission pathways. Even if the exact two- or three-dimensional coordinates of the sensor nodes are not available, these protocols are nevertheless able to function properly. In its place, pressure sensors were used to monitor the force exerted by the water as it raced alongside biosensors. Water pressure is the factor that defines the depth of the sensor nodes, which is necessary for the establishment and maintenance of routing patterns. As a result of these protocols, the network may be expanded with a minimum of effort. For the purpose of gathering the required depth or pressure, the pressure sensor that is embedded into the sensor node may simply do so. Due to the fact that these protocols are scalable, they are very useful for activities that take place underwater, including as military operations, surveillance, and exploration. The reason for this is because these applications often need a comprehensive seabed survey rather than a focused one.

Unfortunately, the poor channel performance adds salt to injury to the already tough challenge of reliably sending information via UASN in the unpredictable and hazardous sea environment. Through the development of two different approaches for UAWNs, our study addresses these challenges. Therefore, while selecting a candidate for the next data forward, depth and noise-aware routing, as described in [69], takes into consideration both the level of vibration attained by connections inside the node as well as the depth of the node itself. In spite of this, it is unable to tolerate channel noise since it only employs a single connection to transmit data. The result of this was the development of a brand new technique known as Cooperative-DNAR. For the purpose of data transmission, it employs the source-relay-destination protocol.

Table 3.4 Localization free Void Avoidance Techniques with and without mobility

Author	Protocol	Routing Strategy	Problem Addressed	Merits	Demerits
Qadir, Junaid, et al[69]	Energy balanced localization-free cooperative noise-aware routing protocols	The location free reliable routing protocol for void avoidance	Reliable delivery of information	Data delivery ratio is increased	Overhead in terms of control packets exchange

Javaid, N,et.al [70]	Delay Sensitive Routing Protocol	Routing protocols sensitive to delay as an improvement to localization-free routing scheme	It eliminates large number of transmissions	Minimized total energy consumption, transmission loss And average end-to-end delay.	Duplicate packets transmission, high energy consumption in dense networks and high loss in terms of transmission due to distant transmissions of medium-depth nodes .
Tariq, et.al [71]	Distance based reliable and energy efficient (DREE) routing protocol	. DREE aims at improving the reliability between nodes by selecting the next forwarding nodes based on link quality.	Void avoidance	DREE extends network lifetime not only by providing energy balancing but by reducing number of transmissions required to deliver a packet successfully.	Prediction is challenging

Nazareth.et. al [72]	Location-Free Void Avoidance Routing (LFVAR) protocol	Void-node during routing under location free category	void-node is a fundamental challenge	reducing the end-to-end delay, lower energy consumptio n, higher PDR, and throughput	Life time is not considered

Enhancements to routing systems without localisation can be achieved by delay-sensitive protocols such as DBR, EEDBR, and AMCTD. Described in [70] is a popular void-avoidance routing scheme. As a result, less information is lost because to heat and friction. The updated AMCTD finds the optimal data packet forwarder by determining the PF equations for sensor nodes in a network with varying densities, where a sensor node with more neighbours is considered better. We can ensure very low end-to-end latency by making use of adaptive mobility of courier nodes, which allows for very little decrease in network performance.

The previous work proposed R-ERP2R, an extensible energy-efficient routing protocol based on distance [71], as an expansion of this system. DREE does not depend on actual distance and is hence location-agnostic as well. Two things are accomplished by this routing protocol. 1) DREE handles physical distance differently than its related protocol R-ERP2R. Second, an underwater network has never before used a link quality estimator based on fuzzy logic (F-LQE) as DREE has done. In addition, DREE improves the channel lifetime by reducing the number of transmissions required to successfully deliver a packet. The goal of DREE is to improve the overall system's consistency by selecting forwarding nodes based on the quality of the links between them.

Long delays in transmitting packets to their destinations are caused by void-nodes, one of the major issues with routing. The void-node is an integral part of UASNs and influences network uptime, packet loss, and latency. Location-Free Void Avoidance Routing, a protocol for preventing network voids, is the subject of the research. To make UASN networks more robust, it instructs nodes not to transmit data to empty spaces. Also, LFVAR can figure out the optimal way to recover from voids at every UASN void node. This is why it's working to improve energy efficiency, routing throughput, packet delivery ratio, and end-to-end latency all at once.

3.6 Void issue are handling by various techniques in Underwater Acoustic Sensor Network

This page will first go over the void problem and its possible solutions, before moving on to the void avoidance acoustic sensor network.

A heuristic technique

To address the gaps, a heuristic technique uses past experience to uncover recovery paths [73] and arrive at a workable response. There is a vast variety of network architectures and gaps that heuristic approaches can be adjusted to meet. There are advantages and disadvantages to these strategies. While heuristics might simplify solutions, they cannot ensure packet delivery. They do not follow any strict guidelines in order to simplify things and make the procedures more widely applicable in UASNs. In most cases, knowing when to employ heuristic methods requires theoretical evaluations. Each heuristic technique and all of its variants can be evaluated for efficiency and effectiveness using the results of the theoretical evaluations.

For optimal data relay node selection, they employed a hybrid of the Sparrow Search Optimisation and the Grey Wolf Algorithm. Efficiently increasing Packet Delivery while minimising latency, overall packet loss, and energy consumption is the goal of the proposed Hybrid-SSO. An adaptable approach that factors in mobile nodes is crucial for extending the network's lifetime. The movement of nodes creates articulation points (AP) in a network's architecture. One way to think about AP is as a network of bridges in a graph. Problems with transmission reliability and network fragmentation are the results of AP. One approach that was proposed for anticipating network partitions was the Cat Swarm Optimisation [74] in searching mode. The algorithm's tracking mode selects the cat nearest the projected AP and directs it to go in that direction to keep the network from splitting. By reducing the frequency of disconnections and transmission breakdowns, it increases the network's lifespan. Reduced transmission failure and retry rates might aid in node energy conservation.

Our Q-learning ant colony routing protocol (QLACO) employs a reward mechanism in conjunction with artificial ants to determine the optimal global routing path, thereby resolving the issue of link instability in UASNs [75]. By utilising a reward function (PDR), QLACO optimises its packet delivery rate in response to changing ocean conditions. To solve the issue of empty space, we also propose an anti-void approach.

The results of the simulation show that compared to QELAR and DBR, QLACO performs better in terms of package delivery frequency (PDR), energy consumption (EDR), and delay (latency).

Learning Techniques

To better handle voids, it can be useful to apply different learning methodologies [76]. By examining their previous data, nodes in the ocean might potentially learn more about their performance. The transient nature of the nodes means that data stored more than a few years ago could not be relevant anymore. Therefore, in a dynamic environment, nodes can act as an IA. The fraction of packets transmitted in a certain direction that actually arrived at their destination can be determined by a local maximal node after some time has passed. The neighbourhood maximal node then has the option to send packets in the same or a different direction. The decision's resilience is fine-tuned by looking at how the ocean's fluids behave.

In this research paper [77], we introduce the Q-learning based EEBDG routing protocol, which allows for balanced data collecting while consuming less energy. By analysing the leftover energy of each FN, it sorts them into multiple categories based on the energies of his neighbours. In the event that energy is the primary selection factor, the network will use its energy resources in the most effective manner possible. An further advantage that comes with using efficient FN selection is the expansion of the lifespan of the network. The void node recovery mechanism, on the other hand, is rendered ineffective if the topology of the network is altered. Developing a QLEEBDG adjacent node (QL-EEBDG-ADN) approach was done with the intention of preventing QL-EEBDG void holes from occurring. It keeps communication going by finding new paths across the network's neighbours in order to carry out its functions. During the process of performing simulations, the following performance indicators are taken into consideration: the energy tax (PDR), the packet delivery ratio (PDR), the network stability period (NSP), and the network stability period (1SP).

Consequently, we offer an RLOR that integrates the advantages of aggressive scheduling and the design-enhancing-understanding method in this work [78]. An RLOR approach to integrated networking takes into account the status of the nodes' perimeter in addition to the order in which they are selected as top relay nodes. Applying RLOR to sparse networks enables packets to swiftly traverse the dead zone and go onwards through its recovery mechanism.

The number 79. The void routing problem and energy savings can be addressed with UASN. The goal is to find the best routing options by using an evolutionary algorithm-based incentive structure. Many things would have to be considered for this to work, including depth data, link quality, energy, and latency. Eligibility check using the communication range technique is defined before forwarding. By doing so, routing loops can be eliminated and trap nodes can be located. To further cut down on unnecessary redundancy and packet collisions, an Obligatory forwarding-based scheduling system was also under development. In order to establish the packets' forwarding priority, this method looks at their Q values.

Table 3.5 Void issue are handling by various techniques

Techniques	Algorithm/ Techniques Name	Void avoidance localization	Achievement
Heuristic technique	Hybrid Sparrow Search Optimization with Grey Wolf Algorithm	Localization based Void Avoidance	Life time of network is improved by Void Avoidance
	Cat Swarm Optimization	Location based Void Avoidance	Life Time, Energy Consumption based on void avoidance approach
	Q-learning aided ant colony routing protocol (QLACO	Location Base	Energy Efficiency is achieved by anti-void avoidance methods
Learning Techniques	QLEEBDG adjacent node (QL-EEBDG-ADN) scheme	Location Based	Packet Transmission is enhanced using void avoidance
	Reinforcement learning-based	Location Base	Reliable Data Delivery

	opportunistic routing protocol		
	ROEVA	Location base	Energy consumption is achieved
Network topology control	Adaptive multi-zone geographic routing protocol	Location Base	Consumption of energy is done by detecting of forwarded node
Flooding	Directional Flooding Routing (DFR)	Pressure Base	Packet Delivery
	PSOGLFR	Depth	Energy Consumption
	Angle Based Flooding	Location	Energy consumption
Hybrid	Hop-by-hop vector-based forwarding	Location	Void handling - energy efficiency
	Vector-based void avoidance protocol	Pressure	Void handling-vector approach
	Reliable Energy based Routing Protocol	Location	Data Transmission – Energy Management

PROPOSED WORK

4.1 Model of Energy Consumption

Due to the difficulty of charging or replacing batteries in water, energy consumption is a major concern for UWSNs. Estimating and studying UWSN node energy usage is critical for optimizing network performance and extending network longevity.

Three primary parts make up an energy consumption model for UWSNs:

1. Transmission Energy: The amount of energy needed by a node to send data across the acoustic channel is represented by this component. Factors including transmission power, distance between sender and receiver, and modulation method all play a role in the total amount of energy consumed.
2. Reception Energy: This particular component is a representation of the amount of energy that a node consumes while it is receiving data over the acoustic channel. The overall quantity of energy that is spent is determined by a variety of factors, including as the received signal-to-noise ratio (SNR), the sensitivity of the receiver, and the kind of modulation.
3. Processing Energy: This component represents the energy consumed by a node to process data locally. This includes tasks such as data aggregation, compression, and encryption. The amount of energy consumed depends on factors such as the processing power of the node and the complexity of the processing task.

Optimum utilization of energy in UWSNs may be accomplished by the use of a variety of techniques, including duty cycling, adaptive gearbox power regulation, and data aggregation, on the one hand. To lessen the amount of power that is used, adaptive transmission power regulation adjusts the transmission power in accordance with the distance between the transmitter and the receiver, and duty cycling will switch off the radio at certain intervals. The quantity of data transfers and, hence, the amount of energy that is spent may be decreased by the process of data aggregation, which includes aggregating many data packets into a single one.

All things considered, UWSN design relies heavily on energy consumption modelling, and it is essential to optimize network performance and prolong network lifetime by comprehending the energy consumption characteristics of UWSN nodes.

The information was transmitted using the model described in References [80, 81]. Energy consumption for data packet transmission is thought to be higher than that of data packet sensing, processing, and reception.

$$"E_{tx}(d) = P_r \times T_p \times A(d)"$$

Where: $E_{tx}(d)$: represents energy consumption to transmit the data.

P_r : represents the required power threshold to receive the data.

T_p : Required time of transmission for successful transmission of data which is calculated by $T_p = M_b / S_v$.

d : Transmission distance

M_b : Size of information package

S_v : Transmission speed of the information package

$A(d)$: Energy attenuation which is calculated by $A(d) = d \quad \times \beta^d$

λ : Energy spreading factor and the value of λ for cylindrical is 1, 1.5 for practical and 2 for spherical spreading and $\beta = 10^{\alpha(f)/10}$ is calculated by absorption coefficient $\alpha(f)$ which is calculated by:

$$"\alpha(f) = 0.11\left(10^{-3} f^2 / 1 + f^2\right) + 44\left(10^{-3} f^2\right) / 4100 + f^2) + 2.75 \times 10^{-7} f^2 + 3 \times 10^{-6}"$$

Where f is carrier acoustic signal frequency in KHZ and

$\alpha(f)$ in dB/m. Communication energy consumption is defined by $C_e = E_{tx}\left(R_t\right) \times t_n$

Where,

t_n : represents the transmission time of node s.

R_t : represents the communication range for node s.

$E_{tx}\left(R_t\right)$: Represents the required communication energy consumption to transmit the one information package.

Movement energy consumption is denoted by:

$$M_e = m_d \times e_{mu}$$

Where m_d represents the movement distance and e_{mu} represents the energy consumption/movement distance.

4.2 Node Sensing Model

UWSNs rely on a "node sensing model" to gather and interpret data from their immediate surroundings. In a typical UWSN network, nodes have sensors that can detect things like water quality, salinity, temperature, and pressure. Underwater surveillance, ocean monitoring, and marine biological research rely heavily on these sensors.

The node sensing model in UWSN typically includes the following components:

1. Sensing Hardware: In this section, the actual sensors that will be a part of the UWSN network nodes are described. These sensors are able to monitor a broad variety of environmental factors, such as temperature, pressure, salinity, and water quality, amongst others. The necessities of the application determine how it should be used.
2. Sensing Software: The software that manages the sensors and gathers data is what this part is referring to. To minimize data transmission, the software can be

programmed to take periodic sensor readings, gather data in response to certain events, or do some processing locally.

3. Data Processing: Among these activities are data fusion, compression, and filtering. Reducing the amount of data transmitted over the network without sacrificing important information is possible with well-designed data processing algorithms.
4. Energy Consumption: This component is comprised of the energy supply that is necessary for the operation of the sensing apparatus, the sensing software, and the data processing algorithms. For the purpose of extending the lifespan of the UWSN nodes, it is essential to optimise the amount of energy that they use.

It is possible to modify the sensing model to fit specific application needs. In ocean monitoring, for instance, sensors can be positioned at varying depths to gauge currents, salinity, and temperature. Placement of sensors near submerged infrastructure, like oil rigs or bridges, allows for underwater monitoring applications to identify any dangers.

The Boolean sensing model in Ref. [82] is used to describe the node sensing.

$$"f\left(p_i,s_i\right) = 1 \text{ if } \left(\sqrt{\left(x_i-a_i\right)^2+\left(y_i-b_i\right)^2+\left(z_i-c_i\right)^2} \right) <= R_s"$$
$$"f\left(p_i,s_i\right) = 0 \text{ if } \left(\sqrt{\left(x_i-a_i\right)^2+\left(y_i-b_i\right)^2+\left(z_i-c_i\right)^2} \right) > R_s"$$

Where, $\left(x_{i,}y_{i,}z_i\right)$ are the coordinates of the node and $\left(a_{i,}b_{i,}c_i\right)$ are the coordinates of cube point and s_i is known as sensing range.

For the cube point p_i, the coverage degree $k(p_i)$ is defined by given function:

$$"k(p_i)=\sum_{j=1}^{n} f(p_i,s_i)"$$

Here n represents the number of nodes. If $f_0(p_i)$ Function value is one then cube point p_i is not covered by any sensor node.

$$"f_0(p_i) = \left\{1k(p_i) = 0\right\}"$$
$$"f_0(p_i) = \left\{1k(p_i) \neq 0\right\}"$$

4.3 Node Movement Model

The term "node movement model" is used to describe how nodes in UWSNs move and navigate when operating in an underwater setting. Nodes in UWSNs are vulnerable to the impacts of waves, currents, and tides, which can make their movements unpredictable and lead to drifting, in contrast to terrestrial wireless sensor networks. It is critical to simulate and assess node movement in UWSNs for optimizing network performance and data collection.

The following elements are usually present in a UWSN node movement model:

1. Environmental Model: The mathematical models that mimic the ocean's depths are what this part is all about. To forecast the movement of water molecules and, by extension, the movement of UWSN nodes, these models can incorporate ocean current, wave, and tide data.
2. Node Mobility Model: The mathematical models that model the motion of UWSN nodes are included in this component. Parameters like as the speed, direction, and acceleration of nodes can be included in these models, which can be either deterministic or stochastic.
3. Network Topology Model: The connectivity of the nodes in the network is what this component is alluding to. Based on the needs of the application, the topology might be either static or dynamic.

The performance of a UWSN can be greatly impacted by the mobility of nodes. and when they move too slowly, they might miss out on data from a wide area. Improving UWSN node mobility is critical to achieving the application's goals.

Node localization algorithms, adaptive routing protocols, and data aggregation techniques are some of the methods that can be employed to optimize node movement in UWSNs. Nodes can be configured to be fixed or move in a predictable manner so that data can be routed through adaptive routing protocols. If you want to optimize your network's routing and data collecting, you can utilize node localization techniques to find out where each node is. To mitigate the effect of node movement on data collecting, data aggregation techniques can be employed to merge data from numerous nodes.

To illustrate how nodes move in response to water currents, the node movement model is detailed in Reference [82].

$$"Rd(0,1) < Pe"$$

Where Pe is a variable, calculated to manage the probability of node movement and this Boolean type expression gives one if the condition is true otherwise 0. The direction of the node movement is represented by given equations:

$$"Xi = Xi + \alpha 1 * randomi(0, mx) * [2 * rd \ (0,1) < Pdx) - 1"$$
$$"Yi = Yi + \alpha 1 * randomi(0, my) * [2 * rd \ (0,1) < Pdy) - 1"$$
$$"Zi = Zi + \alpha 1 * randomi(0, mz) * [2 * rd \ (0,1) < Pdz) - 1"$$

Here $\alpha 1$, mx, my and mz are the coefficient, determining the direction of maximum movement and Pdx, Pdy and Pdz are the probability.

4.4 Routing process of EEOPR

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 consider 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 strategies.

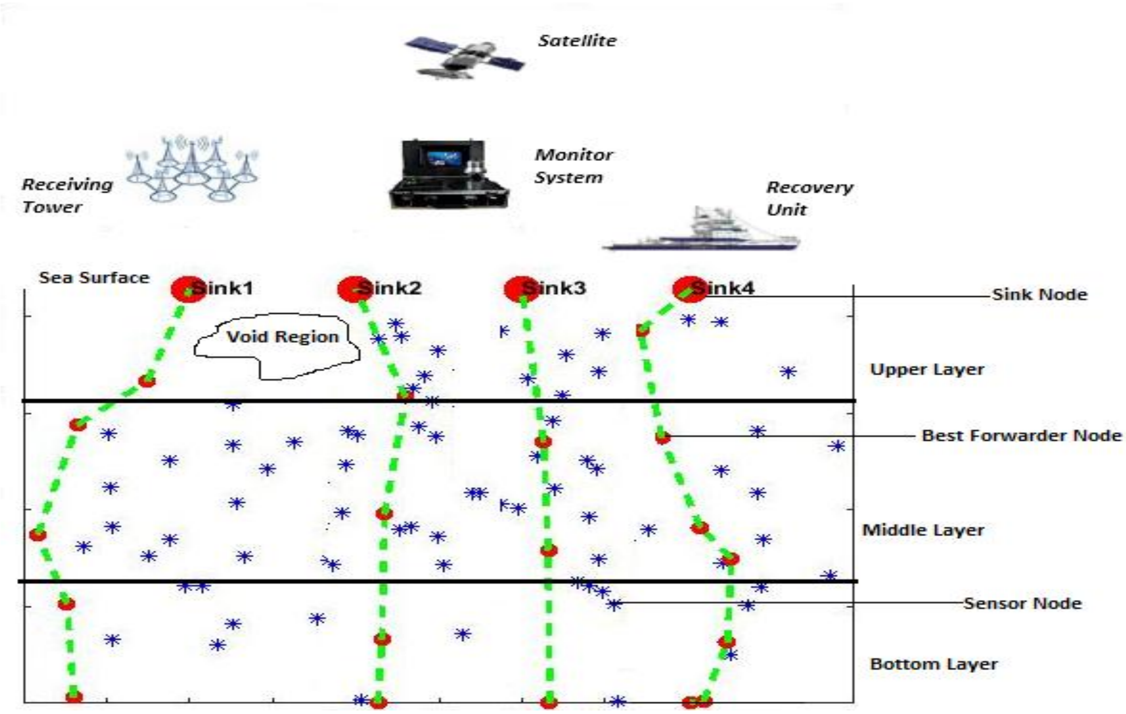

Fig.4.1 Routing Process of EEOPR

4.5 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.

$$P_1 = P_0 Att(x) \qquad (1)$$

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

$$Att(x) = x^k a^x \qquad (2)$$

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

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

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

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

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

$$E_T(l,x) = lP_0 x^k a^x \qquad (5)$$

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

$$E_R(l) = lP_r \qquad (6)$$

4.5.1Calculation 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.

$$P = \rho g d \qquad (7)$$

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 .

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

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

4.5.2 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 .

$$E_R = E_0 - n_d * E_d - n_s E_s - n_r E_r - T * E_I \qquad (9)$$

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_s : Data packets and control packets transmitted

n_r : Data packet received.

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

$$P_E = \frac{E_R/E_0}{n} \qquad (10)$$

4.5.3 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.

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

$$10\log N_t(f) = 17 - 30\log f \qquad (12)$$

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

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

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

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.

$$C(d, f) = B\log_2(1 + SNR(d, f)) \qquad (16)$$

Here, $C(d, f)$ channel capacity acts as link quality [83]. 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.

4.5.6 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 [84] 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.

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

$$A = 2a.r1 - a \qquad (18)$$

$$C = 2.r2 \qquad (19)$$

$$a = 2 - 2(t / Max\_iter) \qquad (20)$$

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 are updated as per their position information. Below mentioned equations are used to compute the updating position.

$$X1 = X\alpha - A1.|C1.X\alpha - X| \qquad (21)$$

$$X2 = X\beta - A2.|C2.X\beta - X| \qquad (22)$$

$$X3 = X\delta - A3.|C3.X\delta - X| \qquad (23)$$

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

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.

$$D\alpha = C1.X\alpha - X \qquad (25)$$

$$D\beta = C2.X\beta - X \qquad (26)$$

$$D\delta = C3.X\delta - X \qquad (27)$$

4.5.7 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.

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

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

$$f(x) = \max(P) \qquad (29)$$

SIMULATION AND RESULTS

5.1 Simulation environment

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 $\alpha = 0.5$ 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.

5.1.1 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.

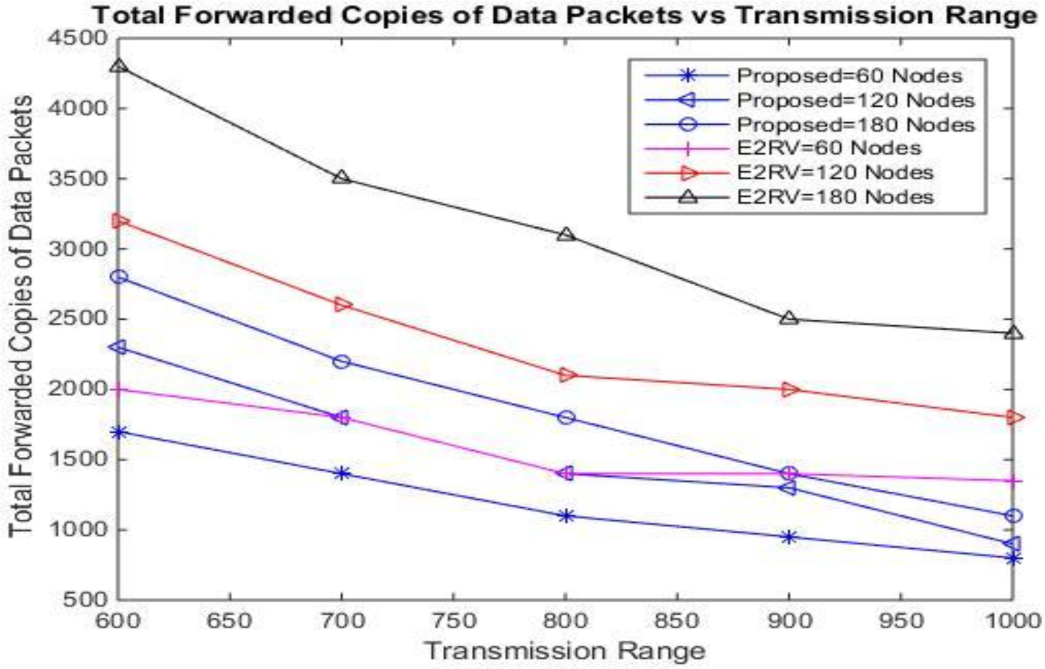

Fig. 5.1 Total Forwarded Copies of Data Packets vs Transmission Range

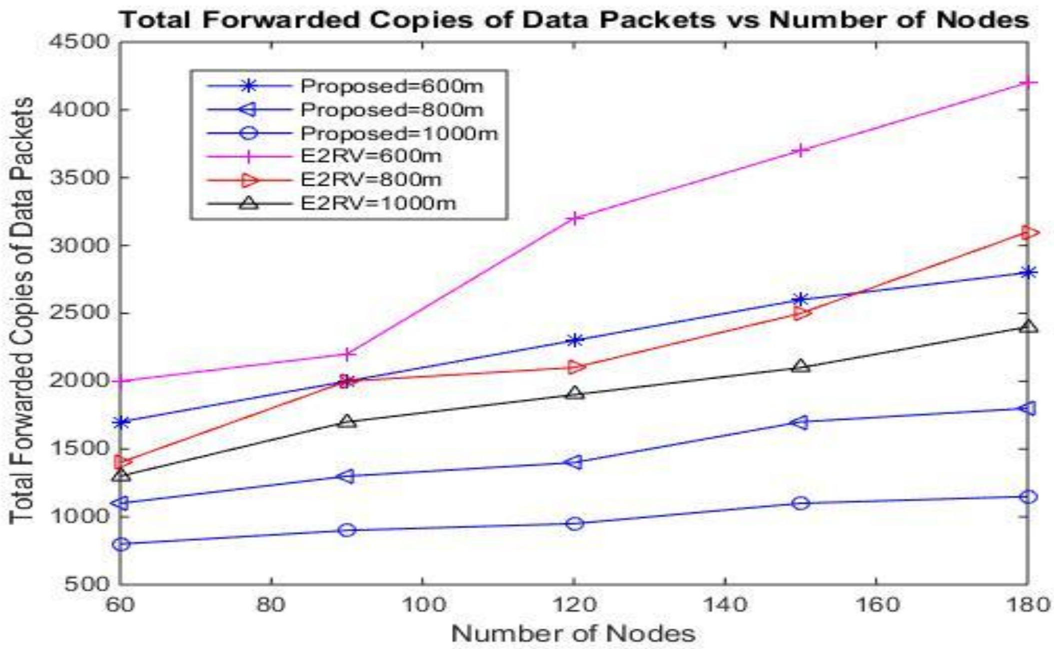

Fig.5.2 Total Forwarded Copies of Data Packets vs Number of Nodes

5.1.2 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.

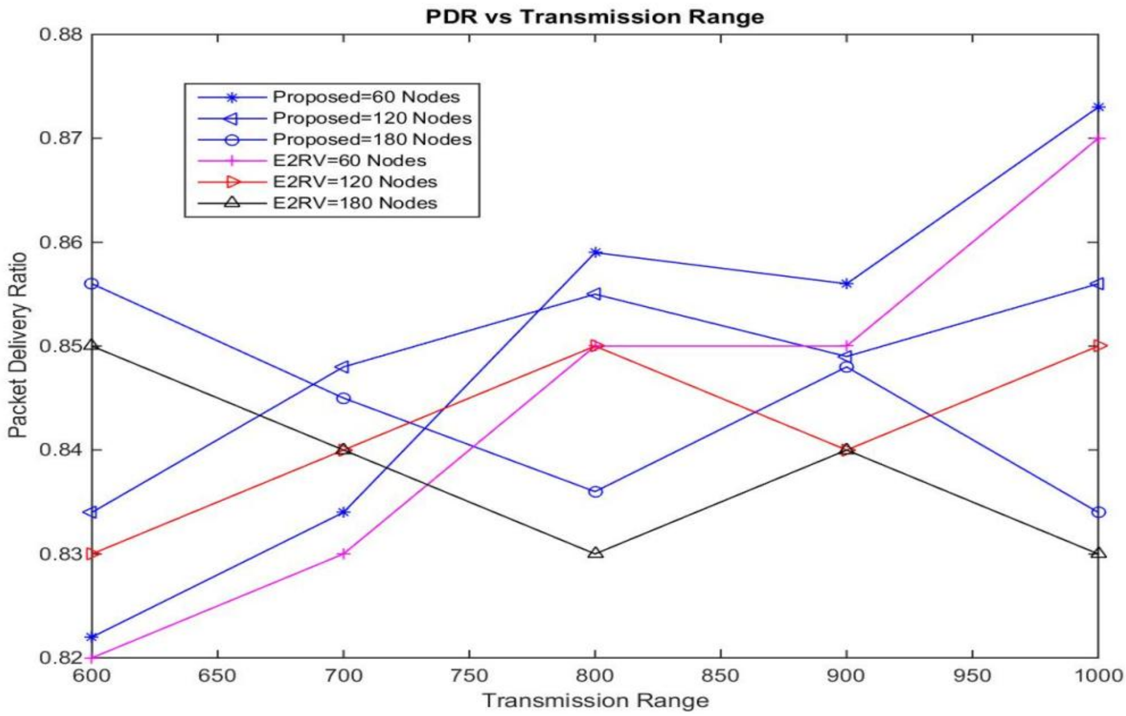

Fig.5.3 PDR vs Transmission Range

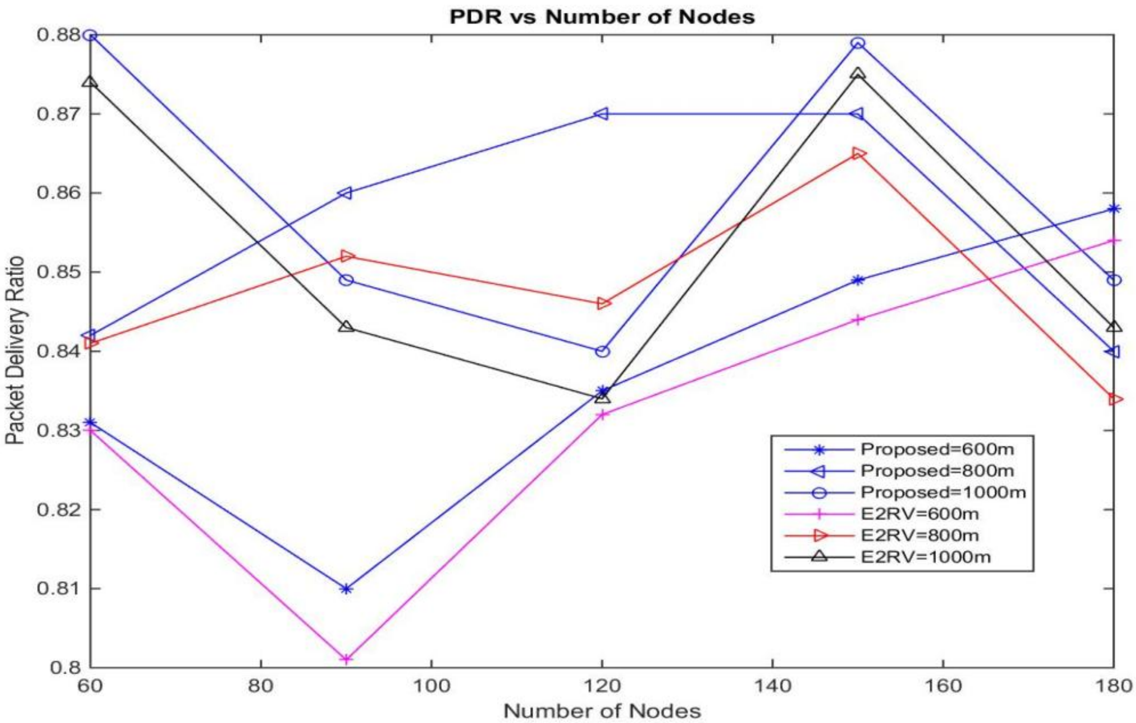

Fig.5.4 PDR vs Number of Nodes

5.1.3 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 rises 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.

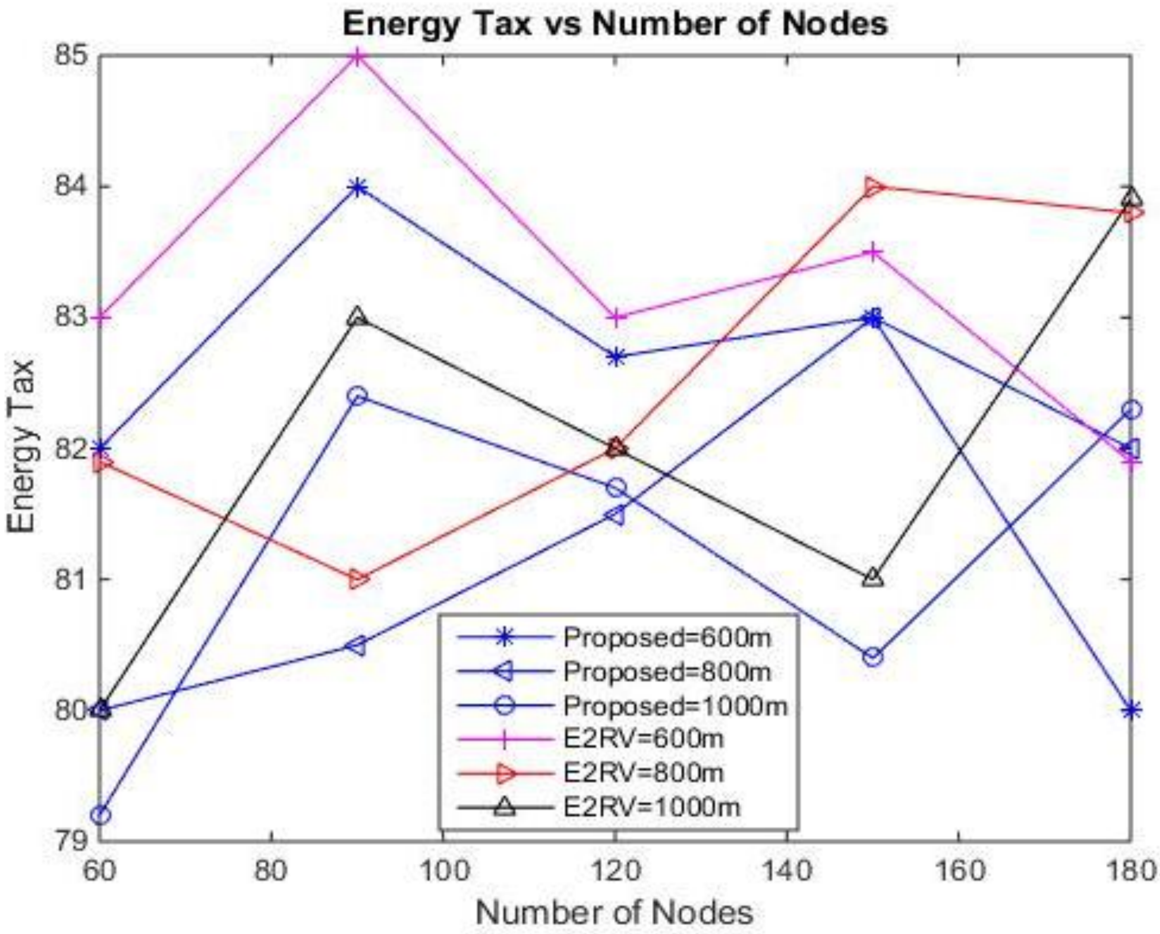

Fig.5.5 Energy Tax vs Number of Nodes

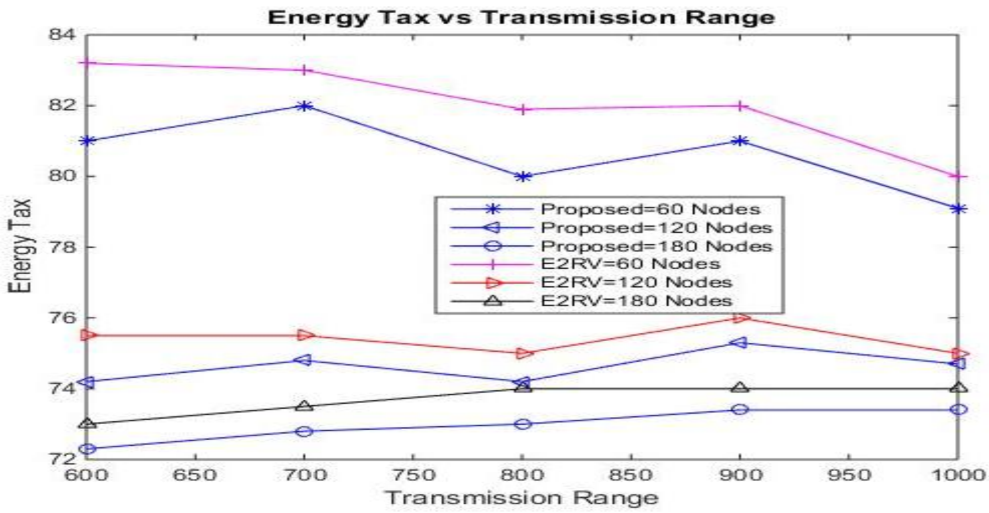

Fig.5.6 Energy Tax vs Transmission Range

5.1.4 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 amount 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.

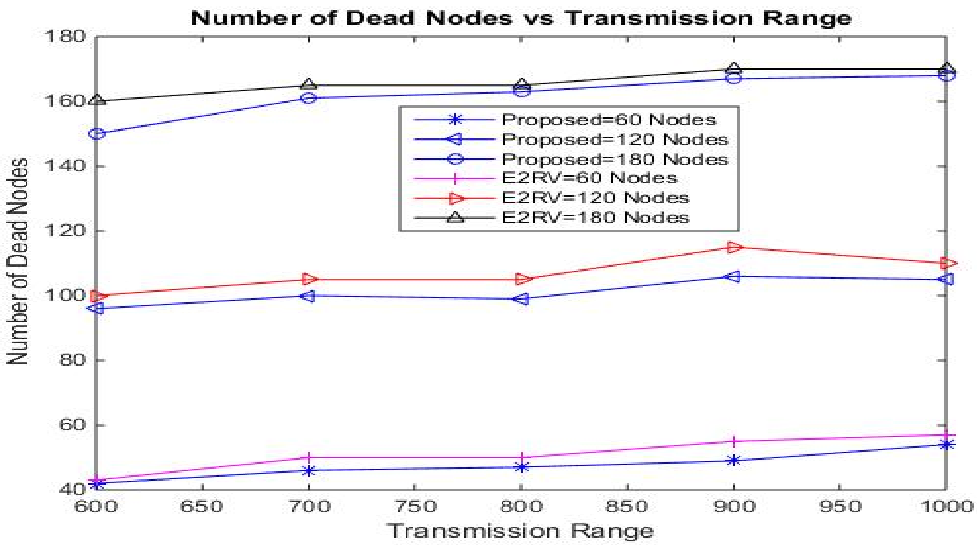

Fig.5.7 Number of Dead Nodes vs Transmission Range

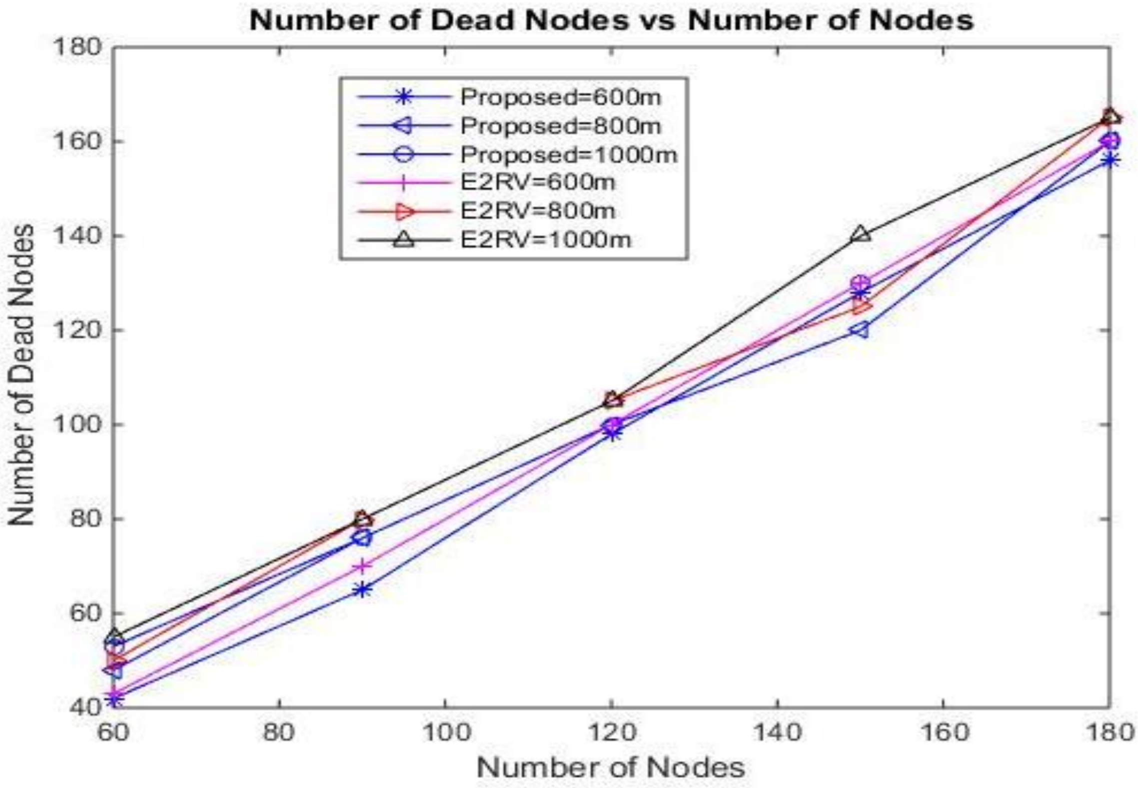

Fig.5.8 Number of Dead Nodes vs Number of Nodes

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 less 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.

5.1.5 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.

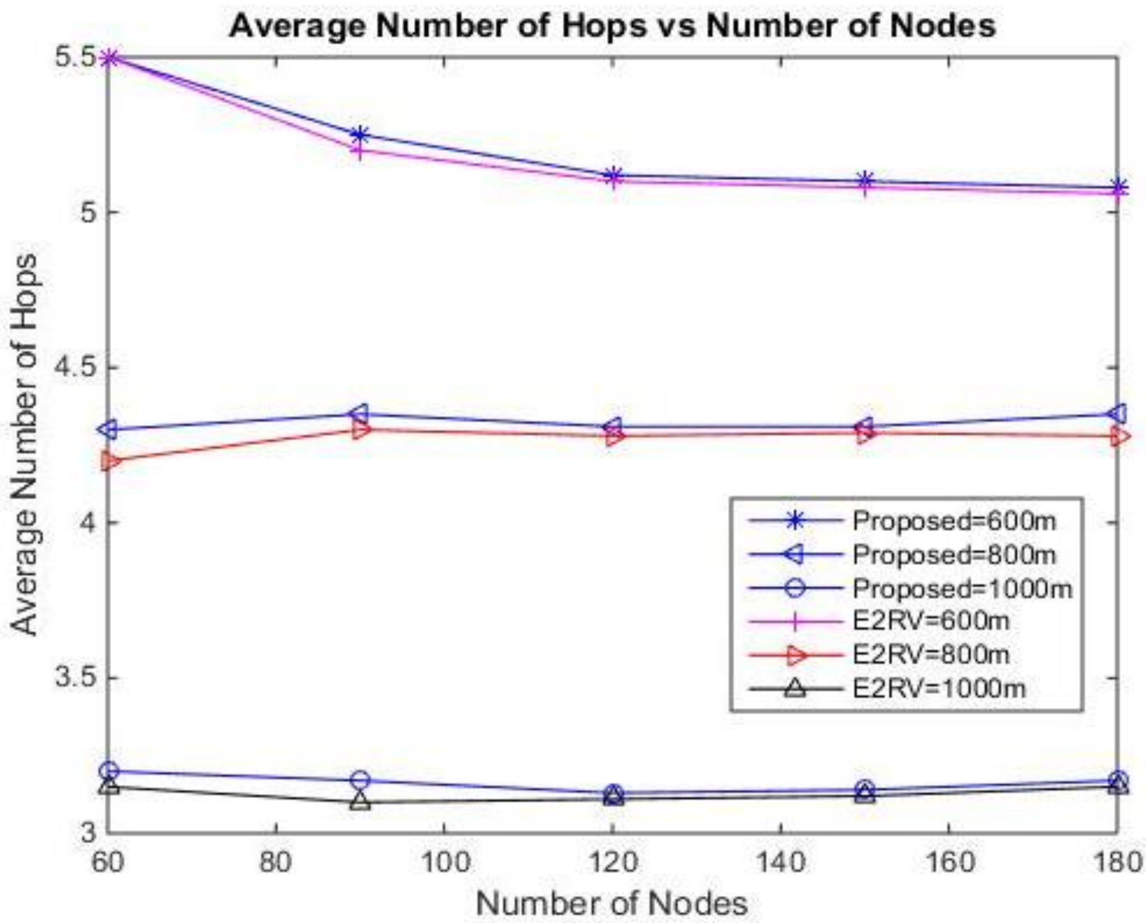

Fig.5.9 Average Number of Hops vs Number of Nodes

CONCLUSIONS

6.1 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.

6.2 Future work

Underwater Wireless Sensor Networks (UWSNs) are an emerging technology that has the potential to revolutionize oceanic exploration and resource management. Void avoidance routing is a critical area of research in UWSNs, as it enables the efficient routing of data packets around areas with little or no connectivity. Here are some potential future opportunities in void avoidance routing in UWSNs:

1. Development of efficient algorithms: One of the key challenges in void avoidance routing is the development of efficient routing algorithms that can identify and avoid areas with poor connectivity. Future research can focus on developing algorithms that are optimized for UWSNs and can handle the unique characteristics of the underwater environment, such as high attenuation and limited bandwidth.
2. Integration with machine learning: Machine learning techniques such as neural networks and decision trees can be used to improve the accuracy of void detection and routing decisions in UWSNs. By incorporating machine learning algorithms into the routing process, UWSNs can achieve greater efficiency and reliability.

3. Optimization of energy consumption: Energy consumption is a critical issue in UWSNs, as nodes are often battery-powered and have limited resources. Future research can focus on developing energy-efficient void avoidance routing algorithms that can reduce the energy consumption of nodes and prolong the lifetime of the network.
4. Implementation of multi-hop routing: Multi-hop routing is a technique that enables data to be transmitted over multiple hops between source and destination nodes. Future research can focus on developing efficient multi-hop routing algorithms that can avoid voids and maximize the use of available bandwidth in UWSNs.
5. Integration with other technologies: Void avoidance routing can be integrated with other technologies such as acoustic communication and underwater localization to improve the performance and reliability of UWSNs. Future research can focus on developing integrated systems that combine multiple technologies to provide robust and efficient communication in UWSNs

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Studies on the review of energy balanced routing in UASN.

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The study in [1] analyses the most recent developments in UASN about design of protocol, along with methodologies used for the research used and the difficulties encountered due to the presence of vacuum. The problem in a procedure depending on received signalrather than a location-based protocol to remedy this. When using SSR, sensor node initialproduces a line byitself at the as well as the sizeof the vector represents the beeper signalingcoming to the sink. The closest node to the vector is formed and given top priority as an applicant for the subsequent hop.By using a void-avoiding technique, data packets are not sent to neighboring nodes. SSR usage decreases energy consumption as well as end-to-end delay (E-ED). UASNs are widely used in disaster prevention, monitoring of the marine aquatic atmosphere, monitoring of pollution, military investigation, and resource investigation. In USWN, end-to-end avenues out of thebasis connecting sink node towards the nodeare followed using the inference aware routing protocol. Inference aware routing protocol avoids the issue of void hole in Depth-Based Routing protocol. The Efficiency in energyand Interference and Route Aware protocol is used in USWN to integrate the straight forwarding and transmissionmechanisms the facts transfer since the start pointto sink node. In terms of energy efficiency, Compared to the DBR, this technique performed best structure because it uses the best relay, fewer hops, and shortest path follow-up to minimize channel losses [2]. Among other sensor nodes, the Optimized Depth-Based Routing (ODBR) approach consumes energy uniformly.

Various protocols based on routing are suggested to enhance packet delivery in UASNs with the least amount of energy and delay cost, with greedy routing strategies being the most popular options. Geographically greedy routing has emerged as a potential technique in sensor and ad hoc networks with the use of localization methods. Geographic greedy routing uses position data to each hop brings data forwardand to final location. [3].

Geographical directionemploys a greedy-forwarding technique every location of nodes searches for the nearby the node which is the most nearby the desired location. However, due to communication gaps or the local maximum phenomenon, greedy forwarding may not succeed. In this case, there's a suitable path from sender to destination, the forwarding node is unable to locate any qualifying nodes along with a good advance being made toward the target, that packet could be loss. The void phenomenon is caused by a number of elements, either separately or in combination, including a sparse topology, transient barriers, and unstable links of nodes.

Elaborating the network's density is a straightforward fix, but it's not always feasible, and even then, it won't completely solve the void issue. To boost route effectiveness, several tacticsboth restoration techniquesoffered to address the issue with wireless and ad hoc networks voids. [4]. Second, the void is movable due to the majority of undersea nodes' mobility. A mobile void may also be caused by the environment. This may occur when a ship travels over an undersea network, cutting off communications this region or creatinga gap consisting followsits vessel.Overall, the properties create use of underwater sensor networks it much challenging for them at operates in movable, three-dimensional holes [5].

1. Main Contribution

i. We also examine the void avoidance protocol algorithm-based both localization-based and localization-free routing protocols, and Depth or Pressure routing schemes in light of the fact that the void avoidance protocol can significantly enhance the routing performance in UASN.

ii. The localization categories are further separated into protocols that take mobility into account, which can offer a wide range of notions for designing routing protocols.

iii. Location and Depth in underwater acoustic sensor networks are used to study the properties of void handling (UASNs)

iv. Talk about void avoidance and how to improve the forwarding strategy when there are problems with sensor node connectivity, as well as its benefits and drawbacks.
v. MAC protocol based Acoustic sensor network also analyzed
vi. Outlining numerous upcoming developments with reference to inspiration and unresolved problems that have come up.

1.2 Evaluation of Void Avoidance Routing Protocol in UASNs

We took into account the distribution of the research publications throughout time based on the publications like Springer, IEEE and Elsevier, ACM, Wiley, and Smith, & Taylor who were evaluated and cited in the research. Additionally, several electronic databases are used, including IEEE Xplore and Science Direct.

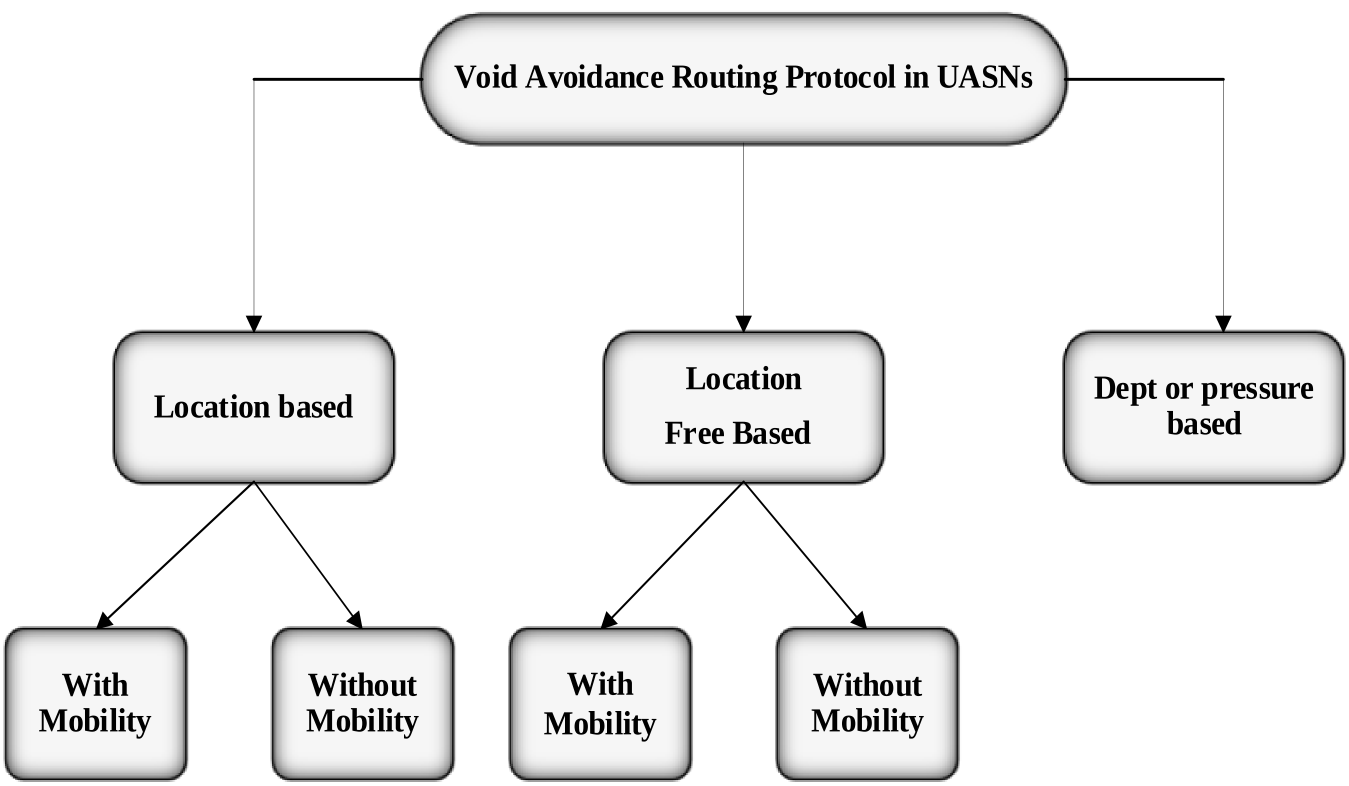

Fig.1.Classification of Void Avoidance Routing Protocol

2. Architecture of Underwater Acoustic Sensor Networks

The special kind at acoustic sensor network called an underwater sensor network allows us to gather data and information about the ocean for use in a variety of applications, including real-time tracking of warships, disaster prevention, environmental monitoring, seismic detection, and oceanographic data monitoring [6].

1-D UASN Architecture: It is a straightforward deployment of sensor nodes in which nodes are placed one at a time and build their independent network. Each node in this architecturehas responsible for collecting and sending information to a distant facility.In this network, communication is typically done using a star connectivity, in which every node transmits data straight at that base station after a single hop [7]. Due to the low connection stability and transmission range of one dimensional UASN, covering complex acoustic environments is exceedingly difficult. All of the components of networks, whether they communicate by radio frequency, optical communication, or acoustic channel, do so using a single-dimension structure [8]. As a result, large data processing is not a good fit for it.

2-D UASN Architecture

We define the network as 2-D, 3-D, and 4-D in the multi-dimensional design of UASNs. At this architecture, we deploy the sensor nodes in the ocean's depth using clusters. Thereare one or more undersea sinks created in this architecture and are in charge of communicating informationand knowledge gained through depths of the ocean to its surface [9]. We used vertical and horizontal transceivers, two different kinds of acoustic transceivers, for this purpose. It uses horizontal transceivers to gather monitored data, deliver instructions and customization information to the devices, and us-sink detectors. Thus long-range transceivers used to relay data to surface stations are called horizontal transceivers. Underwater sensor networks with 2-D architecture often use RF, optical, or acoustic transmission for communication. We choose the topology by examining the underwater application; the two-dimensional architecture may be a mesh, star, or ring.

3-D UASN Architecture:

Many wireless nodes togetheris created for at the undersea environment at various depths using a 3-D architecture. Co-sampling of the three-dimensional surroundingsis beneficial. In this architecture, the cluster is divided according to the division of labor with each cluster head gathering data from its corresponding member and transmitting it to the base station. Intra-cluster communication, which takes place involving the foundation node and the sensitivity node,is one of three types of communication between cluster nodes. The second sort of communication is between clusters of nodes operating at various depths, and the final type is communication between buoyant anchors [10].

4-D UASN Architecture: The organization using a combination of stationary 3-D underwater sensor networks and movable underwater sensor networks is hinted to by this type of architecture. The information from the anchor node is collected by the mobile underwater sensor networks remotely operated underwater vehicles who then transmit it to the remote/base station. These vehicles may be standalone automobiles, underwater robots, boats, or submarines[11]. Depending on how close it is to the remotely operated vehicles (ROVs), each sensor node can relay the data directly to the ROVs. What type of communication will take place between underwater sensor nodes and ROVs, RF, optical, or acoustic communication depends on the information and distance in an underwater environment [12]. While acoustic connections are used when a sensor node is far from ROVs and has little information, radio connections can also be used if the sensor node has a lot of data.

This investigation is a prime motivation to deliver the issue identified with void node evasion under various conditions. It is found that vast majority of the steering approaches utilizes just leftover energy of the nodes and profundity distinction to advance the information bundle. It is further noticed that UWASNs are utilized in different application situations and consider a different component while proposing another steering calculation [13]. There are many difficulties in this field. These are information retransmission, geography the executes, way misfortune and security. These difficulties need scientist consideration. It is important to secure the submerged nodes. This is must lasting task.

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Studies on evaluation of void avoidance routing protocols in UASNs.

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Acoustic communication is the most widespread method of transmission. Acoustic waves, also known as mechanical waves, have a great transmission range but are employed for deep-water transmission that is thermally [1]. (from a few hundred metres to tens of kilometres). Underwater communication, which has that method of underwater communication that has seen the most development, is the sole approach to establish Long-distance underwater wireless transmission among devices. Increased acoustic waves, though, mayencounter pronounced reduction as their travel through water, which will result in just a limited amount of bandwidth being available. However, there are quite a few challanges with the sensor nodes which are as follows-

1. Path loss

Path Loss is the first aspect that we must take into account. The number of packets that must be transferred over a given time and distance in acoustic communication depends on the desired frequency. The impact of time delay may be decreased by reducing the total displacement travelled while simultaneously increasing the transmission power. The impact of path loss may be decreased by reducing bandwidth at total displacement travelled while simultaneously increasing the transmission power [2].

2. Three-dimensionality and Node Movement

UASNs were three-dimensional, and sensor systems that follow the flow of the waterin contrast to terrestrial networks. More packet failures may result from these perforations were three-dimensional of routing path. Because there are more nearby nodes in more directions in 3D UASNs, the hidden terminal problem is more severe. Furthermore, as the node moves, the topology changes continuously. The water velocity, which changes over time, determines the speed of node [3].

3. High and Variable Propagation Delay

Sensing in UASNs communicate underwater using acoustic waves. Underwater, sounds moves at the rate of roughly 1500 m/s. As a result, it results in a significant lag in propagating that has a five-order significance difference greater compared to radio waves. Based on many factors including temperature, salinity, and water depth, the sound velocity fluctuates. The propagation latency must be considered when constructing are void-handling strategies at UASNs.

4. Limited Bandwidth

The acoustic bandwidth in UASNs is significantly constrained as a result of acoustic wave characteristics and ambient noise. This acoustical wavelength and transmission bandwidth affect at the available acoustical range. With submarine devices, the average throughput could be seldom ever reach hundred kilobits per second due to at constrained frequency band [7]. Therefore, when creating void handling solutions, the constrained it is important to consider the acoustic channels wavelength account.

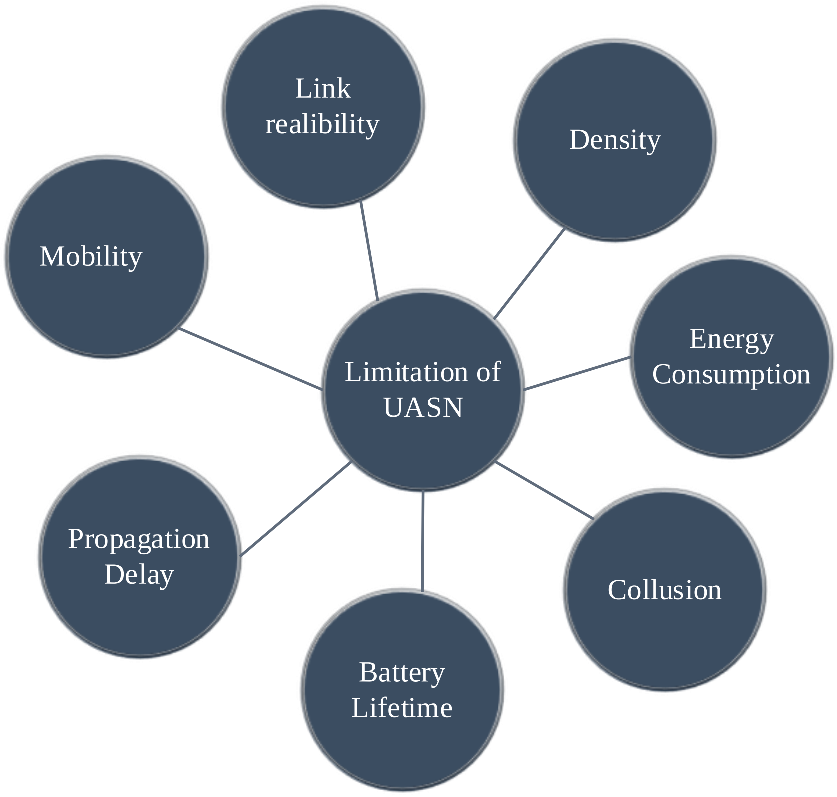

Fig.1. Limitations of UASN

5. Energy Consumption

Another major issue with UASNs is energy usage because they are challenging at repair or even the sensors devices can be recharged. This force used due to such sensing in UASNs is significantly more than that used through detectors on the ground. Accordingly, void-handling solutions in UASNs must meet the fundamental criteria of energy efficiency [5]. These qualities render the terrestrial void-handling approaches completely ineffective and prevent their direct application to the underwater environment.

6. Noises

Man-made noise and ambient noise are the two types of noise that have an impact on acoustic communications. Human activities like operating pumps and shipping are the main sources of man-made noise [6]. Natural occurrences like earthquakes and tides are considered noise in the background Shipping, waves, radiant temperature, and disturbance is at main drivers of that noise.

7. Multipath:

Multipath is the following parameter to take into account. Generally speaking, we separated communication into two categories: single path and multipath. The primary distinction between single and multipath communication is that multipath communication produces Inter Symbol Interference (ISI), a type of signal distortion [7]. Another aspect to take into account is time scattering, which is less of a problem for transmission over vertical paths and more of a factor for transmission along horizontal channels.

8. Delay:

Delay is another significant parameter. Poor communication between nodes occurs in UWSN routing because Multi-hop results in packet loss with such a predicted latency parameter. Acoustic waves travelling at 1500 m/s, typically experience with a 0.67 s/km latency [8].

9. Application of UASN

Although the use of networks in the water has been documented for a long time, the first practical successes only started to become possible in the early 20th century due to evolving technology. Since then, their uses have continued to grow, and today, we can declare that underwater acoustic sensor networks can perform the majority of the functions performed by terrestrial wireless sensor networks in the ocean. Based on its domains, applications of underwater networks can be characterized [9].

Military applications: UW-ASNs are used in these applications primarily to find and discern impediments or goals, which are the core job using sonar devices, especially in army contexts searching for mines and submarines but also fishing.

Environmental applications: In this instance, UW-ASNs measure either the position and speed of an underwater mobile or the properties of the numerous marine environment components (bottom topography, live species, currents, and hydrological structures, etc.).

Scientific applications: UW-ASNs are used in these applications to broadcast signals that underwater scientific equipment can pick up, messages between submarines and surface ships, or instructions to remotely operated systems.

Underwater exploration: In this situation, UW-ASNs are designed to find oil fields or reservoirs, choose where to put undersea cables, and help with mineral exploration.

Surveillance and disaster prevention:

Water sensor can keep an eye on locations used for retargeting, monitoring, and penetration testing such applications. When issuing tsunami warnings or researching the effects of undersea earthquakes, UW-ASNs is utilized to assess seismic activity.

10. 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 local 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 [10].

11. 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 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.

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CERTIFICATE OF PARTICIPATION

This is to certify that Mr. Deepanshu, Department of Computer Science, P.K.University, Shivpuri (M.P.) India **has participated in the International Conference on "Secure and Trustworthy Machine learning in India" organized by the Department of Science and Humanities, Dr.N.G.P Institute of Technology, Coimbatore-641048, Tamilnadu on June 13,2024.**

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