AN IMPROVED ADDRESSING BASED ENERGY EFFICIENT ROUTING PROTOCOL FOR UNDERWATER WIRELESS SENSOR NETWORKS

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Candidate of **Master of Science in Computer Science (MSCS)** at the National University of Modern Languages do hereby declare that the thesis **An Improved Addressing Based Energy Efficient Routing Protocol for Underwater Wireless Sensor Networks** submitted by me in partial fulfillment of MSCS degree, is my original work, and has not been submitted or published earlier. I also solemnly declare that it shall not, in future, be submitted by me for obtaining any other degree from this or any other university or institution. I also understand that if evidence of plagiarism is found in my thesis/dissertation at any stage, even after the award of a degree, the work may be cancelled and the degree revoked.

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ABSTRACT

Title: An Improved Addressing Based Energy Efficient Routing Protocol for Underwater Wireless Sensor Networks

Underwater Wireless Sensor Networks (UWSNs) are networks of independent sensors set up in underwater environments for a range of purposes, such as oceanography, surveillance, environmental monitoring, and underwater exploration. The particular characteristics of underwater communication offer special difficulties for UWSNs, in contrast with conventional wireless sensor networks that function in terrestrial environments. Power consumption in UWSNs presents a difficult problem for increasing network lifetime. Network applications experience delays, disruptions in power, and a reduced network lifetime as a result of these problems. The current routing techniques intended to tackle these problems falls lacking in terms of improving packet delivery ratio, ensuring dependable data transmission, and selecting routes efficiently. An important consideration in the design of an energy-efficient routing protocol for UWSNs is choosing the best routes with the fewest energy losses. For UWSN, this study proposes an entirely novel routing approach. It enhances the packet delivery ratio, lowers delay and energy consumption, and improves application performance. The Addressing based Energy-Efficient routing (AEER) for UWSN protocol is the one that is being proposed. There are three main steps in the AEER technique. Information spreads across the nodes in the network field during the first stage of network setup. The routing table calculates and stores the first-hop neighbors' distance information. The provision of a scalable addressing mechanism, which updates IDs based on hop distances from surface sinks before to data transmission, is the next stage. The third phase is packet routing with energy balancing, in which all surrounding node data recorded in the routing protocol is utilized for route planning and data forwarding. A routing-based, energy-efficient, effective multi-path routing protocol called E2LR, H2-DAB, and 2H-ACK is compared with AEER. The AEER protocol has been evaluated using NS2. According to experimental studies, AEER uses 8%, 12%, and 10% less energy than E2LR, H2-DAB, and 2H-ACK. When compared to H2-DAB and 2H-ACK, AEER increases packet delivery ratio by 20% and 15%, respectively, but from E2LR it reduces by 10%. Furthermore, when AEER is compared to the E2LR, H2-DAB, and 2H-ACK protocols, it reduces end-to-end latency and improves network lifetime.

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LIST OF ABBREVIATIONS

UWSN	-	Underwater Wireless Sensor Networks
MuLSi	-	Multilayer Sink
H2-DAB	-	HOP by HOP DYNAMIC Addressing Based
2H-ACK	-	2 HOP-Acknowledgement
DBR	-	Designated Backup Router
EERBLC	-	Energy-efficient Routing protocol Based on Layers and Unequal Clusters
PDR	-	Packet Delivery Ratio
VBF	-	Vector Based Forwarding protocol
TORA	-	Temporally Ordered Routing Algorithm
MATLAB	-	Matrix Laboratory
E2LR	-	Energy Efficient and Link Reliable
TM2RP	-	Triangle Metric Based Multi Layered Routing Protocol
LQE	-	Link Quality Evaluator
AEER	-	Addressing Based Energy Efficient Routing protocol
QoS	-	Quality of Service
NS-2	-	Network Simulator-2
AHV	-	Autonomous Underwater Vehicle
HH-VBF	-	Hop by Hop-Vector Based Forwarding
TBRL	-	Terminal Ballistics Research Laboratory
E2ED	-	End to End Delay
UVLC	-	Underwater Visible Light Communication
ESEERP	-	Enhanced Smart Energy Efficient Routing Protocol
AHH-VBF	-	Adaptive Hop by Hop-Vector Based Forwarding

LIST OF SYMBOLS

T_{ri} - Packet Reception Time

T_{si} - Packet Transmission Time

i - Packet Identifier

Ei - Initial Energy

Ef - Final Energy

E_{t} - Total Energy

$\mathrm{Er.\,Ni}$ - Remaining Energy of Node

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I shall also acknowledge the extended assistance from the administrations of Department of Computer Sciences who supported me all through my research experience and simplified the challenges I faced. For all whom I did not mention but I shall not neglect their significant contribution, thanks for everything.

DEDICATION

This thesis work is dedicated to my parents and my teachers throughout my education career who have not only loved me unconditionally but whose good examples have taught me to work hard for the things that I aspire to achieve.

CHAPTER 1

INTRODUCTION

1.1 Overview

Communication in UWSNs is predominantly based on acoustic signals, enabling nodes to exchange data, transmit messages, and coordinate actions. However, there are issues with acoustic relationships, like low bandwidth and long delays in propagation. and susceptibility to noise and interference. These factors require efficient communication protocols and algorithms tailored to the underwater medium.

UWSNs must also address power management challenges since replacing or recharging sensor node batteries underwater is often impractical. To prolong network lifetime, power-efficient algorithms and duty cycling mechanisms are employed, enabling nodes to change between different states of being active and asleep to conserve energy. In recent years, researchers have been exploring innovative solutions to overcome the limitations of UWSNs, such as improving acoustic communication performance, developing energy-efficient protocols, and enhancing data fusion and aggregation techniques to reduce redundancy and optimize data transmission.

UWSNs have a extensive variety of applications, contributing significantly towards the understanding of underwater environments and supporting various industries. Their deployment has facilitated advancements in marine science, resource exploration, environmental protection, and underwater monitoring, ultimately leading to a better understanding of our planet’s oceans.

The key components of UWSNs are underwater sensor nodes. These nodes are prepared with various sensors to gather data about the underwater environment, such as temperature, pressure, salinity, pH levels, and water currents. Additionally, UWSNs may include sensors for detecting specific substances, seismic activities, or the presence of marine life.

UWSNs often operate in remote and challenging underwater environments, making sensor node battery change or recharging difficult. To maximize network lifetime, UWSNs employ energy-efficient communication protocols and power management strategies. Nodes may alternate between active and sleep states to conserve energy. The motivation for this research is to develop different underwater network routing protocols and require comprehensive training to raise their level of performance.

1.2 Motivation

Humans have been fascinated by the ocean for eras. Since that water is essential to human existence, using the advancements in science and technology. It was only in the last century humans solemnly started researching the undersea world, that was the situation insufficient before. Underwater routing protocol play an essential role in detecting, gathering, and sending sensed data from underwater sources, as well as transferring this data to the onshore data collection center. Although further study is needed to improve the performance of underwater network routing protocols and, their applications are in demand. Understanding the origins of natural disasters like hurricanes, sea storms, tsunamis, etc. requires an understanding of how the oceans affect the climate over the land inhabited by humans. Unmanned exploration with self-configuring and communication Capabilities are necessary, nonetheless, because of the harsh maritime environment (such as extremely high temperatures and strong water pressure) and other unpredictable events. As a result, autonomous exploration encourages the development of automated underwater sensor networks and underwater communication protocols.

Underwater routing protocols are used to sense, collect, and transmit sensed data from underwater sources and then send this data to the onshore data gathering center are essential. To enhance the performance of underwater network routing methods, however, more study is needed. In the modern world, underwater networks are used for a variety of purposes, including incursion detection, seismic activity supervision, reducing disasters, oil and gas exploration, and pollution monitoring. Although in high demand, these applications need this technology to be improved in order for them to function effectively and gather information in an efficient manner.

1.2.1 Environment for an underwater scenario

About 70% of the surface of the Earth is composed of fascinating and diverse ecosystems called underwater environments. These ecosystems can be found in a variety of places, from deep ocean depths to shallow coastal locations. Here are some common traits and distinctive qualities of underwater scenarios:

Coastal Zones: Depending on the depth and light penetration, the water is separated into many zones. These zones include the epipelagic zone, commonly referred to as the "sunlight zone," the mesopelagic zone, the "twilight zone," the "midnight zone," the "abyssal zone," and the "hadal zone". Each zone has its own unique flora and fauna that have been suited to the conditions there. Pressure and Light With depth, light penetration drops off quickly, resulting in a variety of organism kinds and their low-light adaptations. Additionally, pressure rises with depth, putting highly stressed creatures under enormous pressure.

Marine Life: An amazing variety of marine life, from small plankton to enormous whales, can be found in underwater habitats. The most diversified and productive ecosystems are coral reefs, which also serve as vital habitats for a variety of marine organisms.

Exploration: Due to technological advancements, underwater exploration is becoming increasingly feasible. With the aid of submersibles, remotely controlled vehicles (ROVs), and autonomous underwater vehicles (AUVs), scientists may more precisely examine and record the deep ocean.

Human Interaction: For ages, humans have engaged in activities such as fishing, shipping, and leisure pursuits like diving and snorkeling that involve interaction with underwater habitats. To reduce negative effects, responsible tourism and sustainable practices are essential.

Research and Discoveries: New species and ecosystems are continually found in the ocean, despite significant advancements in ocean exploration. We are learning more about the global significance and interdependence of these areas through ongoing research. Working underwater has distinct difficulties because of the low visibility, high pressure, and demand for specialized tools. To navigate these conditions safely, divers and researchers must get extensive training and follow safety procedures.

Overall, underwater settings are fascinating places that conceal a lot of secrets and are crucial to preserving the health of our world. The health of marine life and all of humanity depends on research into and protection of these ecosystems.

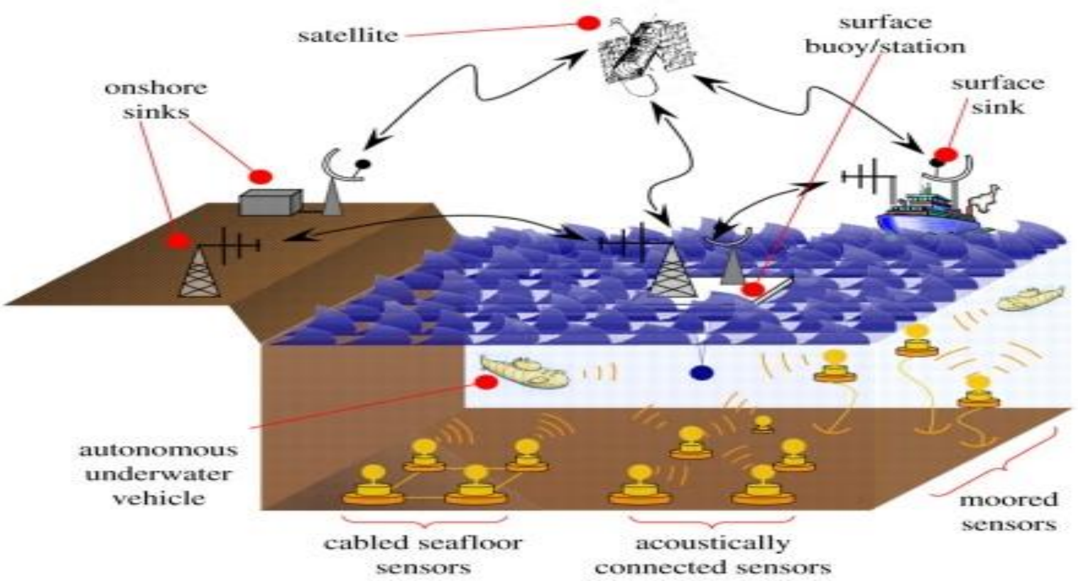


Figure 1.1: Different types of node deployment in UW-ASN[47]

1.2.2 Constraints in UWSN

Due to the underwater environment's unique restrictions and difficulties in contrast to wireless networks on land, underwater wireless sensor networks (UWSNs) must overcome a number of particular obstacles. Several of the significant constraints in UWSNs include:

i. **Limited communication range:** The communication range of underwater sensors is constrained by water's substantial absorption and attenuation of radio frequency signals. Since the range is frequently significantly less than in terrestrial situations, numerous sensor installations are required to keep the network connected.

ii. **Transmission delays:** Radio signals in water propagate more slowly than they do in the air, adding to end-to-end communication latency in UWSNs and causing significant propagation delays.

iii. **Heavy propagation loss:** Because water scatters and absorbs electromagnetic waves, the attenuation of waves with distance increases. As a result, the signal strength rapidly drops, making it difficult to establish trustworthy communication relationships over long distances.

iv. **Underwater mobility:** The positioning and stability of underwater sensors can be impacted by underwater currents and aquatic animal movements, which can result in dynamic network topologies.

v. **Energy limitations:** The majority of UWSN nodes run on batteries, and swapping out or replenishing batteries underwater can be time-consuming and expensive. Energy efficiency is therefore essential for the network's long-term viability.

vi. **Harsh environmental circumstances:** Underwater sensors need to be made to survive harsh environmental conditions such high water pressure, corrosion, biofouling, and other things that can affect their performance and longevity.

vii. **Scalability:** The deployment of a large-scale UWSN can be expensive and complicated, and controlling a large number of underwater nodes presents major difficulties.

viii. Routing and localization of data: Due to the specifics of underwater communication, conventional routing and localization protocols created for terrestrial networks are insufficient. New protocols must take into account things like 3D location, mobility, and communication range restrictions.

To effectively solve the special difficulties of wireless sensor networks underwater, it's essential to use specialized protocols, algorithms, and hardware designs. To improve the functionality and dependability of UWSNs, scientists and engineers are still coming up with creative ways.

1.2.3 Applications of Underwater Wireless Sensor Networks

Due to the ability to perform of these networks to gather and transmit data in an underwater environment, Underwater Wireless Sensor Networks (UWSNs) are used in a wide variety of industries. Listed below are a few of the major uses for UWSNs:

i. Environmental monitoring: In lakes, rivers, and the oceans, UWSNs can be used to monitor a variety of environmental characteristics. To evaluate the health of aquatic ecosystems, they can monitor the water's salinity, temperature, and dissolved oxygen content, and pollution levels.
ii. Oceanography: UWSNs are essential to research in this field because they give scientists the ability to examine phenomena such as marine life behavior, ocean currents, and underwater topography.
iii. Offshore industries: UWSNs are used in offshore sectors including oil and gas exploration to watch for potential leaks, corrosion, and structural integrity in equipment, pipelines, and undersea structures.

iv. Disaster prevention and early warning: Early warning systems for catastrophes can be placed in disaster-prone areas to keep an eye on undersea seismic activity, tsunamis, and other natural calamities. To lessen the impact of such occurrences, they offer early warning systems.

v. Underwater communication and navigation: UWSNs are employed to help underwater vehicles, underwater drones, and autonomous underwater vehicles (AUVs) communicate and navigate.

1.3 Problem Background

Human involvement in the exploration of underwater resources is restricted by the harsh underwater environment. Self-configuring underwater sensor nodes are essential, exchange their locations, effectively and dynamically interact with additional sensor nodes send data regarding the surface sink nodes in order to conduct systematic observations, ensure seamless communication, and get the best results. The drawback of established exploration methods is that they necessitate human engagement, which is impractical given the unpredictable nature of the aquatic environment, the size of the monitored region, and the associated costs. In the end but not least, traditional techniques are not scalable in the absence of inter-node or offshore communication. As a result, they are unfit and unreliable for comprehensive coverage. As a result, unmanned solutions like routing protocols are needed for effective monitoring and data collecting for extensive real-time applications. a system where nodes are capable of data relaying and communication with an offshore control system in addition to being able to efficiently communicate with one another using acoustic wireless networks. The next section discusses problems with designing routing protocols.[47]

In an acoustic medium, underwater network protocols have a large propagation delay. This means that to have the ability to able to improve network lifetime with respect to energy and to prevent additional delay in the slower sound medium, the overhead of communication needs to be constrained by a minimal threshold. Utilizing the limited battery power that each node in an underwater network has is one of the most crucial problems in these networks. In routing protocols, energy efficiency refers to delivering routing services while using less energy for tasks like reducing interference, error rates, retransmission attempts, and message delivery and reception. [47].For example protocol Hop-by-Hop Dynamic Addressing Based (H2-DAB) routing protocol for UWSN was suggested by Ayaz et al[26] A few of the nodes that sense in this architecture are anchored at the bottom. The remaining sensor nodes are placed at various depths, ranging from the top to the bottom, and they are free to move horizontally and gently oscillate vertically. Dynamic addresses are assigned to these floating nodes. These addresses have a date of expiration. It shortens the life of a network.it forwards the data through nodes up to 9 layers and if data send beyond the 6 layers, it expires. AS a result, H2 -DAB not only uses too much energy during the information distribution phase, but also reduces the network lifetime by continually using the same path. The addressing scheme is also not expandable past the ninth layer to learn about nodes at the following hop, which have a longer delay, a node sends a request message, during the data forwarding phase. In addition, the source of the data, or its origin, cannot be determined because H2 -DAB forwards the data using the hop ID rather than the source ID. Finally, the H2 -DAB has packet losses since it lacks a dependability mechanism.

Studies [48] have shown that Hop-by-Hop ACK (HbH-ACK) technique only requires two nodes because the receiving node will respond with an ACK when it has successfully received a packet devoid of errors. The sender node might toss the current packet and proceed to process the following data packet after receiving the ACK. This HbH-ACK has no issues in stable areas like wired networks, but in unstable situations like underwater, where nodes can disappear for a variety of reasons, this standard ACK approach is less appropriate. The sending node will discard the data packet in operation currently after getting the ACK, leaving the receiving node as the sole node in the network with it.The receiving node may be unable to determine the next hop for extended periods of time in order to reach the destination. During this time, it may run out of power and die, or it may experience any number of failures due to fouling and corrosion issues.When node transfer the data through hop address the source node initiate a request to its neighbours and then choose the smallest hop id for data forwarding.Every time it chooses smallest hop address so in this way it decreases network lifetime.

Another issue of concern is proposed in [46] which is about underwater localization-free routing protocol called E2 LR that takes into account the difficulties of high energy consumption, particularly during the phase of information distribution, increased end-to-end latency during the phase of data forwarding, and network lifetime. Details in the article demonstrate how E2 LR lowers energy usage through its control flooding technique and lowers end-to-end delay by taking assessment of link quality into account. Sometimes it chooses the incorrect node when moving nodes. Because of this, the link quality was constantly changing and being calculated for many times. Energy consumption also increases.

It has also been observed that some protocols, such as H2 – DAB [26] and DBR[49], do not offer any method to employ next hop nodes alternately, compromising the network lifetime. They repeatedly use the same nodes instead of offering any energy-balancing plan or alternative node selection for the subsequent hop. As a result, communication gaps are created in the network when some nodes die too soon.

1.4 Problem Statement

Few protocols exist that make use of the addressing scheme to forward data from one hop to next. H^2-DAB is one such protocol that used an addressing scheme to forward the data and is very simple in its approach. This scheme can only provide addressing to nine nodes in a sequence and if there are more nodes, this scheme fails to provide any addressing to those nodes and hence they cannot take part in data forwarding [26] . Moreover, data forwarding in H2-DAB and its latest variant 2H-ACK only use one parameter i.e. the address assigned to it [48]. It only uses the address that has shortest hop count. Consequently, the network lifetime will decrease because it always forwards the data using the same node. This research is to address these issues and to make this protocol energy efficient and enhance network lifetime.

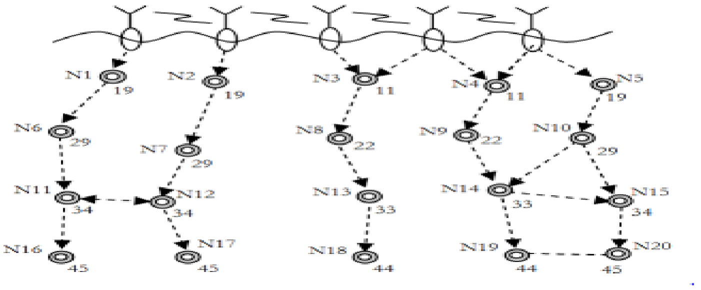


Figure 1.2: Assigning HopID's with the help of Hello packet [26]

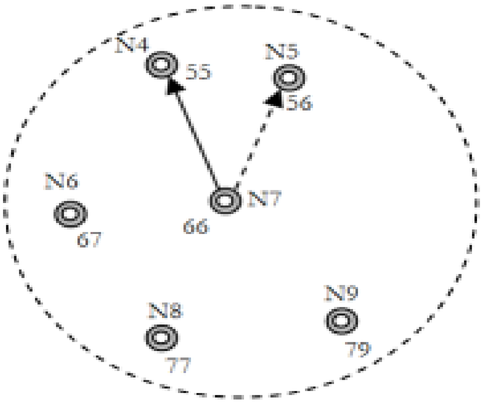


Figure 1.3: Selecting the Next Hop[26].

1.5 Research Questions

i. How to provide a scalable addressing scheme to nodes for data forwarding?

ii. How to increase energy efficiency and prolong protocol lifetime in a network?

1.6 Aim of Research

The aim of this research is to design and implement routing systems for underwater networks that will increase network lifetime and improve scalability, discover an efficient path on a hop-by-hop basis, and always maintain contact nodes aware of their energy condition. Together, these strategies will improve network lifetime, decrease energy usage, and end-to-end network delay while enhancing packet delivery ratio.

1.7 Research Objectives

i. To design and develop an addressing scheme that provides a scalable addressing mechanism.

ii. To design and develop the scheme that enhances the network lifetime and energy efficiency of the protocol

1.8 Scope of Research work

Due to the particular challenges and possible applications in the underwater environment, the field of study on Underwater Wireless Sensor Networks (UWSNs) is wide and constantly increasing. Creating energy-efficient data collection, processing, and communication algorithms to extend network lifetime and lessen the requirement for regular battery replacement or recharge. Constructing effective and dependable communication protocols that can cope with underwater environment restrictions such high latency, constrained bandwidth, and acoustic interference. Environmental monitoring, marine research, underwater exploration, offshore industry, and defense applications are just a few of the areas where advances in UWSN research could leave a big impact.

1.9 Thesis Organization

The remaining sections of the thesis are organized as follows:

After giving some history on the topic, Chapter 2 looks at analogous issues with underwater networks. A classification and discussion of the positive and negative aspects of the existing beacon-based underwater routing techniques are provided. A thorough operational working comparison of the several underwater network protocols is also given.

Chapter 2 finally addresses the research gap that was utilized to create and refine the routing protocol.

Chapter 3 goes into great length about the routing protocol's design, which is oriented on scalability and energy efficiency. It lists the problems and solutions for the benchmark routing protocols.

The objectives of the methodological plan are explained in detail in Chapter 3. It gives information on the parameters utilized in the simulation of the proposed protocol as well as the simulation framework, channel model, and node energy model.

Chapter 4 offers the construction of a reliable, energy-efficient and dependent on distance protocol for hop-by-hop routing is detailed in Chapter 4. Schemes for data forwarding, energy balancing, and information distribution are provided and well explained with examples. Additionally, flowcharts of the schemes that describe how The protocol that was suggested for routing behaves are also provided.

Performance simulation analysis of the planned routing protocol was also covered in Chapter 4. We examine the outcomes of utilizing a number of performance metrics, including packet rate, hop ids, and node mobility. Furthermore illustrated and explained with a range of figures is a comparison between the proposed routing protocols and evaluate routing algorithms based on the packet delivery ratio, end-to-end delay, network longevity, energy consumption during the data forwarding phase, and energy consumption during the information distribution phase.

Chapter 5 summarizes the work's major contributions and discoveries, along with some potential directions for the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Underwater Wireless Sensor Networks (UWSNs) are a type of network that allows for the communication and exchange of data between underwater devices, such as sensors, vehicles, and buoys. Oceanography research, environmental observation, and surveillance are just a few of the uses for UWSNs.The features of the underwater environment, including as the strong attenuation of radio signals, provide special difficulties for UWSNs, the unpredictability of acoustic channels, and the limited energy and computing resources of underwater devices. As a result, UWSNs requires specialized hardware and software solutions to overcome these challenges.

Acoustic communication is the most widely utilized communication method for UWSNs. Acoustic waves can travel long distances underwater, and can be used to transmit data between underwater devices. However, acoustic communication is also subject to various challenges, such as signal distortion due to multipath propagation, noise interference, and limited bandwidth. To address the challenges of UWSNs, researchers have developed various techniques, including adaptive modulation and coding, energy-efficient routing protocols, and localization algorithms. These techniques aim to optimize the performance of UWSNs in terms of energy consumption, data dependability, and communication range.

Overall, UWSNs have the ability to take part an important role in various underwater applications, and ongoing research aims to improve its dependability and performance in difficult underwater conditions.

2.2 Routing Protocols for Underwater Wireless Sensor Networks

Various metrics are used by every UWSN routing algorithm to route sensed data from sensor nodes to sinks. These metrics also have an impact on the routing's overall performance. Some routing algorithms, for example, route information to the node with the greater RSSI value after comparing the signals from its neighboring nodes. This type of routing system always maintains a high connection quality when forwarding data, however it ignores energy balance. Certain additional routing algorithms might rely on the depth information of the nearby nodes while data is being forwarded.

The neighboring node with the lowest depth below the water's surface receives the data using these protocols. These routing protocols always select the farthest nodes, which may or may not have better link quality, but they also may or may not have lower overheads and better energy efficiency. Their delivery ratio appears subpar most of the time, though. Contrary to certain academics who have utilized it to create besides their routing protocols, other routing protocols do not need the sensor nodes' positions. in order to transport the data from the source to the sink. Generally speaking, routing protocols can be divided into two groups according to whether or not they need location data to function.

2.2.1 Location-based Routing

A location-based scheme in underwater wireless sensor networks (UWSNs) can be used to accurately determine the location of underwater sensor nodes. This is important because it enables the network to perform location-aware tasks such as environmental monitoring, tracking of marine life, and underwater surveillance. Once the location is determined, the device or user reports this information to a central server or a peer-to-peer network, depending on the specific protocol architecture.

2.2.2 Location-free Routing

A location-free scheme in UWSN (Underwater Wireless Sensor Networks) refers to a localization method that does not require sensors to have GPS or other location tracking devices. In a UWSN, determining the location of sensors can be challenging because of the short communication range and the high attenuation of wireless signals in water. Traditional localization methods, such as GPS or triangulation, are not always feasible or accurate in UWSN environments. A location-free scheme typically relies on other types of information that can be obtained from the sensors.

Ali et al [1] proposed that Due to their significant and unique challenges as well as their wonderful applications, underwater acoustic wireless sensor networks (UA-WSNs) require careful consideration while designing and configuring an algorithm. These networks tend to work and run for longer periods of time and to be more stable due to their energy-efficient operation. The ideal network layout minimizes the number of hops a message has been transmitted and received, saving energy and minimizing channel effects on data. Still, the significant energy consumption in cooperative techniques makes it difficult. Additionally, synchronizing time and data is a key component of cooperation. The article proposes two algorithms—the multilayer sink (MuLSi) algorithm and its dependable variant, MuLSi-Co—that overcome these issues. Instead of a solid single construction, the first algorithm suggests a multi-layered network structure and places the washbasin in the ideal location. The number of hops between the sender and sink are decreased as a result.

Additionally, choosing the optimal forwarder among nodes based on the distance to the node from the sink improves and adds value to network performances. It is wise to select the top transmit from the node that is nearest to the washbasin. Due to a singular data exchange link, the algorithm does not, however, meet the criteria dependable performance. In contrast to conventional algorithms, the suggested strategy doesn't require node position information.

Because the sink node's battery can be changed, the authors of this research [2] presume that the sink nodes' energy are boundless. In the meanwhile, they probably assume that the underwater sensor nodes have equivalent beginning energy and equivalent range of communication. Furthermore, underwater sensor node energy is only used once. Each underwater sensor node has a depth sensor installed. Delivery is considered to be successful once one of the sink nodes receives the data packets. They proposed that the energy efficient routing protocol based on layers and clusters (EERBLC) is a routing system requiring locality that has been suggested. The high energy consumption, lengthy high error rate and overall latency issues are addressed by this protocol. This protocol layers the underwater monitoring region, clustering the sensor nodes at each step. The three stages of the EERBLC are cluster formation, transmission routing, cluster maintenance, and cluster update. Results show that EERBLC can greatly improve network lifetime, energy usage, throughput, delivery ratio, and efficiency measured by end-to-end delays.

A technique for dynamic hierarchical grouping of 3D underwater sensor networks is proposed in [3] and is according to various using characteristics to make decisions. The simulation findings demonstrate that DHCDGA may enhance network coverage and data gathering reliability in addition to successfully balancing the network's energy consumption and extending network lifetime.DHCDGA displays good results. Researchers discuss the current state of their work and an in-depth analysis of the various underwater routing methods in this article[4]. They divide the underwater routing protocols into three groups based on their characteristics: procedures based on geographic information, data, and energy. Angle adjustment approach results from the authors[5] were compared to DBR results, demonstrating that the suggested technique performs greater to DBR in terms of data transfer, end-to-end latency, and energy consumption in both crowded and sparse network situations. Nakas et al [6] offered a survey of both traditional and contemporary procedures that have been suggested for achieving energy-efficient routing in WSNs.

The proposed protocol [7] is WDFAD-DBR with improvements. This protocol succeeds in reducing energy tax, enhancing PDR, and reducing packet drop at the expense of E2ED. The higher quantity of packets that are successful managed transmission power lower of Etax. By using a high node density channel for forwarding, packet drop is reduced, and as a result, PDR is enhanced. By examining additional neighbour data, like remaining energy and depth, in the densely packed nodes channel, duplicate packets are decreased. In this study [8], researchers suggested CORS, an opportunistic routing technique for sparse UWSNs. Researchers used data from topology to enlarge the selected applicant set, which helped to solve the void problem. In order to combine interflow network coding and opportunistic routing in CORS, forwarding with opportunistic coding technique was created. They also created coding using a sliding window technique and a decoding technique based on sliding windows for reducing coding overhead and decoding overhead, respectively.

An entirely novel UWSN routing method called DMDBR has been put out in this research[9]. The algorithm takes into account a network with numerous surface-deployed sinks. It has been thought about how tides and ocean currents can cause nodes to migrate horizontally and vertically. A phase called beaconing has been added to help select a good forwarder to direct packets to the sink. Only when the forwarder's calculation of residual energy indicates that there is enough energy available to transmit both the delayed and new packets. For various node densities, Matlab was used to simulate the algorithm.. The results show that, in compared to DBR; DMDBR greatly increases network lifetime and total delay, and throughput. In the case of DMDBR, the total quantity of packets transmitted by the network is likewise larger. DMDBR has a somewhat higher residual energy in the network at the point where networking stops working than DBR, though. The lack of forwarder nodes following the death of the majority of nodes is blamed for it. For the next generation of UWCNs, researchers offered a thorough analysis among the most recent energy-related works harvesting and renewable energy supply approaches [10]. This was followed by a thorough discussion of the potential possibilities for UWC field research. Finally, we summarized our work before wrapping up the review. In order to create pathways towards a green IoUT, It is Our objective is that this evaluation was useful will help network designers come up with fresh ideas and new plans that address the underlying issue of energy usage in UWSNs.

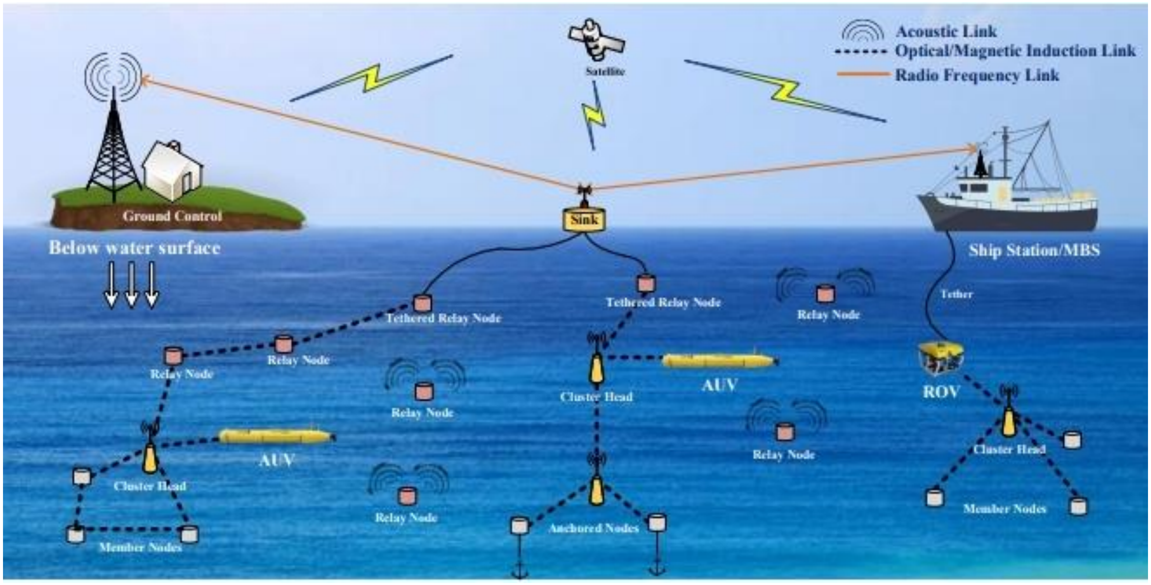


Figure 2.1: Underwater wireless communication network scenario [10]

Qadir.J et al[11] illustrates that According to the instability and roughness of the aquatic environment, it is difficult to send information reliably in underwater wireless sensor networks because of the channel's unfavorable behavior. To meet these issues, this research offers two protocols: DNAR and Co-DNAR. Five equal zones are created throughout the network, each containing five small sinks. The network is divided, and small sinks are placed, ensuring that at the intended location, the most packets are received. The destination node in DNAR is chosen based on its lowest noise level and lowest depth level in the path of origin-destination. In highly dynamic networks, distribution is limited to nodes closest to the sink, minimizing the end-to-end latency. In contrast, when network mobility is reduced [12], distant nodes are allowed to transfer their data packets, increasing the end-to-end delay.

The proposed approach [13-14] raises PDR and lowers overall energy use, both of which lead to a reduction in dead nodes. This method makes advantage of the depth data, next-to-next distance, residual energy, and holding time for choosing the best forwarder. To transfer the data packet, the node with the smallest distance and the most remaining energy will be chosen as the best forwarder. The MATLAB simulation compares E-VAR with Intar and backward-forwarding in terms of the average hop-count, the number of reachable and unreachable nodes, and the distance to the sink.

This study proposed a complete cross-layer networking system that included sleep mode management; intelligent routing with relay load balancing, TDA-MAC scheduling, multi-node ARQ, and a network discovery protocol for data collection in UASNs.The protocol [15] stack was tested through lake trials on university hardware and implemented. Lake on the York Heslington East campus. The tests showed that the network could self-organize into efficient dual-hop topologies for assembling seven undersea sensor nodes' worth of data at one chosen master node. However, in certain cycles of network discovery, a number of nodes experienced wildly inconsistent connection as well as relationship quality, leading to less trustworthy network topologies for subsequent data collection. The proposed technique[16] has been put into practice in MATLAB, and comparisons with the E2RV methodology have been made in terms of Packet Delivery Ratio (PDR), the quantity of inactive nodes and energy tariff. The suggested method lowers overall energy usage and increases packet delivery ratio (PDR), This thus lowers the quantity of dead nodes.

The research [17] described how various Location-Based Opportunistic Routing Protocols proposed for UWSNs worked and assessed how well VBF and HH-VBF, two significant protocols, performed using Aqua-Sim scenarios. These protocols' effectiveness is assessed in both typical network environments and networks with communication gaps. They observe that these protocols perform worse when there are communication gaps in the network. Researchers could create more effective techniques for underwater habitats with voids with the help of the insights from this publication. The key concerns raised by the various underwater-based hybrid communication scenarios by UVLC technology[18] critics about signal propagation and channel impairments are summarized in this work. Additionally, it can be difficult to deploy UWNs with greater modulation techniques over long-distance communication in the marine industry. As a result, various hybrid communication systems are examined in light of requirements and geographic contexts. Considering the aim of completing stable increased data rates with decreasing impacting elements like disturbances and channel deficiencies in the physical layer link, the modems in the IoUT networks may feature some advanced signal tools. This research helps to the resolution of a variety of channel impairment issues and offers a summary of current project plans and outlooks for the 5GB networking setup in this specific domain.

Wei.X et al[19] proposed a brief summary of dependable gathering of data methods in UWSNs has been provided in this work. It can be divided into trustworthy connection and path for dependable navigation and travel in hop-by-hop data collection in AUV-aided data collection. Different researchers have concentrated on various network levels and approaches during data collecting. Reliable data gathering methods have been thoroughly examined for each model and stage, and numerous difficulties have been taken into account and resolved. Various MAC schemes, retransmission techniques, and coding dealing with bit error and packet collision have all been studied individually for the reliable connection techniques. Existing reliable routing methods mostly concentrate regarding the void issue by using a particular routing approach. When using AUVs, unlike hop-by-hop transfer architecture, it is important to consider the best design for AUV navigation and path planning. This opens up new potential and poses new obstacles. Finally, a number of areas for future research are highlighted in an effort to improve UWSN data collection accuracy.

The proposed algorithm [20] is an upgraded version of WDFAD-DBR that addresses possible challenges to the effective performance in WDFAD-DBR without significantly sacrificing E2ED, PDR, cost, or other characteristics. RPSOR uses an opportunistic strategy rather than a greedy method to enhance the performance of UWSNs, in contrast to WDFAD-DBR. By including information about the subsequent forwarding zone in the priority function, RPSOR ensures dependability while reducing the possibility of void holes and packet loss. In this paper[21], researchers introduce a hybrid radial/linear topology routing system tailored for acoustic underwater networks. By simply permitting the construction of numerous connections via one intermediate node, it can likewise be used with ease in hexagonal or rectangular grids. For monitoring medium-sized maritime regions like estuaries, fishing zones, or important geological features, such networks make an intriguing topology. The protocol is intended to reduce the expenses associated with administering such a network, provide robust resiliency, and reduce the amount of time that sensitive data takes transferred by the nodes. With developing the protocol to prevent collisions that could happen when routes are being initialized and maintained, researchers have decreased the energy usage. Additionally, it does not call for extra sensors. When compared to reactive protocols, this proposal's proactive protocol achieves a low packet forwarding delay. Although the effort required in order to prevent crashes causes the initialization's convergence time to be significant, once the routing pathways have been constructed, the packet forwarding latency is fairly short, decreasing computing cost.

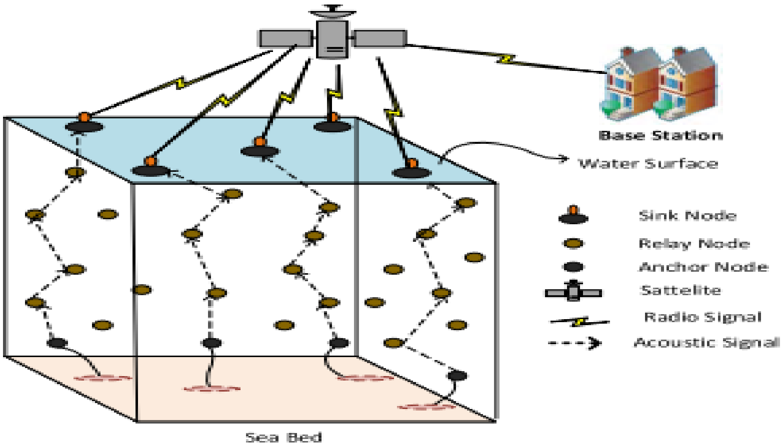


Figure 2.2: Network Architecture [20]

Developing robust links is a crucial necessity for I-UWSN and smart environments. As a result, experts [22] have looked into the metrics that are impacted by weak link reliability. Dynamic topology is a key contributor to the weak link dependability, and its effects can be seen in the metrics of packet delivery ratio and transmission loss, network longevity, and the amount. Due to the water's constant flow, dynamic topology develops. As a result, it is impossible to create a trustworthy link for a long period. Because Short-term dependability is achievable, In this study, we have suggested TBRL for the protocol of dynamic topology routing. Initially, TBRL uses a topology discovery technique to determine the general location of each sensor node. Only nodes depth is taken into account as an input parameter for node positioning. Furthermore, they compared the packet delivery ratio of 2N-RM to that of 2H-ACK and 3H-RM. The simulation results demonstrate that TBRL outperforms state-of-the-art methods. The findings show that TBRL is a superior procedure for monitoring and communicating with underwater sensors to support the concept of smart cities. In the future, we'll employ machine learning methods to select paths more efficiently. The present research [23] demonstrates the fundamentals of acoustic communication as a fundamental principle for formulating and putting into practice the algorithms, protocols, and services in UWSNs that handle these constraints. First, we looked into UWSN state-of-the-art research in the literature. Then, after identifying UWSN's criteria, we offered a thematic taxonomy. This work analyses the literature from credible and well-known article databases. Examining these classifications enables developers to identify areas for improvement and creates new possibilities for underwater sensor network long-term success. A vector-based forwarding protocol (VBF) approach that requires position information of every network node has been proposed in related research. [24-25].

Hop-by-hop dynamic H2-DAB protocol was proposed by the authors in [26] as a non-localization method for beacon-based approaches. Every sensor has a unique ID known as a "Hop-ID" that is shared with every other sensor based on how many hops it has taken to reach the sink node. The H2-DAB sends out a brief message from the washbasin. The node receiving the message will obtain a Hop-ID. When the nodes rise up, a new Hop-ID will be broadcast in a Hello message.Every node placed near the washbasin will receive a tiny Hop-ID since the Hop-ID increases with the number of depth sensors. Nevertheless, the forwarding node is selected from among the sensors with the lower Hop-ID. Within [27],The authors also created a location-free method based on physical distance, called RERP2R, which is dependable and energy-efficient.

In [28] researchers introduced (TM2RP), a multi-layered routing system for UWSNs based on triangle metrics. The suggested method is a pressure-routing algorithm. that selects the most effective next forwarding sensor from a group of candidates based on super nodes, link quality, and residual energy. The amount of residual energy directly affects how well sensors balance their overall energy consumption. The delivery percentage towards the super nodes is optimized by the connection quality, which helps identify the sender and receiver nodes' most reliable links. As a result, TM2RP integrates these variables to determine route cost. The subsequent forwarding nodes are then selected based on this route cost. In order to suppress redundant packet transmission and prevent packet loss, TM2RP uses an overhead and retransmission method.Using the NS2 Simulator with Aqua-Simprogramme for underwater evaluation, they compared TM2RP's performance against DBR and MRP. Based on the simulation results, TM2RP outperformed DBR and MRP in terms of network longevity, packet delivery ratio, energy consumption, and end-to-end delay.

Parallel to location-free techniques,[29-31] most underwater networking applications are not practically suited for expected transmission cost (ETX), which has been used as a significant network monitoring metric. The key factors to take into account when designing autonomous wireless sensor networks[32] are outlined in this review study. An overview of the potential energy supply options for WSNs is given and addressed, including various solutions for energy transmission and energy collection from ambient sources. By doing so, they emphasize the idea of developing hybrid converter systems that take into account several harvesters and sources. There are a number of difficulties with wireless charging for energy supply that are shown. In actuality, network design should take into account energy conservation at the network level in addition to energy supply.

Researchers present evidence [33] that the WSN system's structure can change depending on the needs of the application. Applications on the ground, underground, and underwater have all been covered by WSN. Energy harvesting, which primarily affects network lifetime, is one of the most crucial parts of WSN design. Single setup networks typically don't have any setup overhead, which has a beneficial impact on stability but a negative impact on network lifetime. The lifespan studythe proactive routing that uses the least amount of energy methods for a homogenous system has thus far been covered. Authors' simulation findings [34] demonstrated their suggested scheme's efficiency and efficacy regarding packet delivery and depth adaptation, and the percentage of void nodes when compared to another method. While designing an opportunistic routing protocol for aquatic scenarios using this topology control of depth adjustment technique, researchers will take into account various service quality factors like the cost to delivery ratio of data and the network life.

The AHH-VBF protocol has been proposed [35] as a solution to the problems with HH-VBF, and it alters the pipeline's direction and radius in accordance with the location information of its neighbors. The holding time is depending on the distance between the current node and the target node, and the data is sent by the higher priority node, which lowers the network's propagation delay. The routing protocols described in [36–37] employ clustering techniques to shorten propagation times and save energy. Member nodes and cluster heads make up the network in cluster-based routing. Because the data is only delivered to sinks after all clustering heads have completed gathering data from the pertinent member nodes, there is a considerable delay from start to finish. Therefore, time-sensitive applications in UWSNs should not use cluster-based routing techniques.

In order to perform particular tasks, such as detection of intrusions, biological observation, or environmental [38], Some wireless sensor network applications [40] necessitate deployment in an unsafe or isolated location, such as target tracking and forest fire detection [39]. Fault Persistent Real-Time Routing has been proposed by the authors of [41]. Epidemic routing is used to avoid the issue that arises when a sensor node fails and the connection is lost. It had a problem with collision detection, though. An approach of routing that avoids voids based on residual energy and depth variance was proposed in [42]. Regarding energy tax, dead node count, and packet delivery ratio (PDR), and other factors, this technique performed well. However the duration of holding remaining energy, and depth were taken into consideration while choosing the best forwarder.

A fully opportunistic routing algorithm (TORA), also known as a TORA, for UWSNs was proposed by the authors in [43]. Throughput and energy efficiency both increased with this strategy. In any case, our approach did not effectively identify the best pathways. The authors have suggested a game-theoretic Q-learning routing algorithm for UWSN in [44]. This strategy worked well in the submerged environment. This strategy was used to online self-monitoring tools and distributed learning. However, this approach resulted in the loss of the data packets.

A UWSN network coding-based routing strategy was suggested by the researchers in [45]. This method uses the multicast transmission concept to decode the encoded packets that are seen from a different network node. In order to extend the useful lives of the networks, this proposal increases the transmission power.

Research [46] proposes an energy-efficient and link-reliable (E2LR) routing system that limits the amount of energy used during the information distribution phase by limiting the amount of hello packets that are sent out. Furthermore, in order to minimize the process's end-to-end latency, E2LR assesses the connection quality using a composite metric for selecting the subsequent hop. It also periodically modifies the energy status to achieve optimization throughout routing activities. The simulation findings show that E2LR outperforms H2-DAB and R-ERP2R in terms of energy efficiency throughout both the data forwarding and information distribution phases.

For wireless sensor networks, Singh et al [50] presented a homogeneous clustering approach that reduces power consumption and increases network lifespan. By assuring a consistent arrangement of nodes within the clusters, the network's lifespan is extended. Based on the holdback value, nearest hop distance, and residual energy of the existing cluster heads, a new cluster head is chosen. Every node in the wireless sensor network is guaranteed to be either a cluster head or a member of a cluster by the homogenous method. The cluster members are uniformly distributed in the suggested clustering algorithm, extending the network's life. Additionally, not every node but only cluster chiefs broadcast cluster creation messages in the proposed protocol. As a result, it increases the sensor networks' lifespan. The focus of this strategy is to lengthen the network's lifespan by assuring a uniform distribution of nodes inside clusters, which reduces the amount of receiving and sending overhead placed on a Cluster Head. The energy constraint of the sensor nodes served as motivation for the research's presentation [51]. In this article, the protocols for effective routing in WSN were put forward. In order to achieve network throughput for WSNs using the HEESR algorithm, they tended to concentrate on and analyze the usefulness and effectiveness of our proposed protocol support for low power consumption. Only two local measurements—the residual node energy and the separation from the base station—are employed in HEESR to choose cluster heads. The usage of just two parameters was intended to streamline the configuration procedure. The whole re-clustering process is minimized in conventional clustering techniques, which significantly affects how much energy is used. According to the simulation results, the HEESR algorithm has better network dependability and scalability than its customers.

Tayyab et al [52] proposed that water currents are constant in the underwater wireless sensor network and they continuously alter the architecture of the sensor nodes. The ideal forwarding routes are altered by node drifting and constant network topology change, which occasionally results in vacant areas. As a result, choosing a path with the least amount of energy consumption requires careful consideration of changes caused by steady water currents. Continuous node mobility is taken into consideration while choosing a route, which improves network performance in general. This article suggests the MIER routing protocol, which makes use of IMU sensor data to monitor node mobility and availability. As opposed to other protocols like GEDAR, WDFAD-DBR, and PSBR, which determine the routing route using a static scheme. Based on node drift, the MIER protocol automatically notifies its neighbors via a beacon. Because there is reduced network overhead, this event-based triggering method maintains the route updated and conserves energy. By attaining lower energy consumption (network lifetime) and a greater packet delivery ratio than the current protocols, the thorough simulation shows that the proposed MIER protocol performs better than those protocols.

Using beacon messages from the sink node to disseminate vital information that helps nodes choose the best next forwarding node is the main goal of beacon aware UWSN routing algorithms. On the basis of beacon data, various research projects have been recommended for the UWSN. For instance, dynamic addressing and data delivery techniques were proposed by Zahid et al [53].Both of the two methods take location information into consideration, but they put more of an emphasis on sharing beacon message information depending on sink node data. The study's objective is to reduce energy usage while enhancing the scalability and reliability of underwater sensor nodes. For underwater sensors. J.Liu e al [54] has also proposed a layering strategy based on multi-layered routing. A costly distributed localization method is not necessary with the pressure-based routing system. In general, DBR lacks an adequate procedure for managing mobility, forwarding data, and recovering from local maxima, which results in higher energy usage. Pressure Sensor-Based Reliable (PSBR) routing is another opportunistic-based data forwarding method that has been suggested for effective data forwarding in UWSNs [55].The PBSR is a sender-based strategy that chooses a forwarder by taking into account a number of factors, such as the link quality evaluator (FLQE), the remaining energy and the depth distance of the sensor.

2.3 Comparison of UWSN Protocols

Under Water Wireless Sensor Networks (UWSN’s) employ various protocols to enable interaction and information sharing between underwater sensor nodes. Here is a comparison of some commonly used UWSN protocols.

Table 2.1: Summary of Protocols

Protocol	Basic Idea	Mechanism	Advantages	Limitations
MuLSi-Co[1]	Choosing the optimal forwarder among nodes depending on the node proximity to the sink, improves and adds value to network performances.	The network layout minimizes how many hops are made between the sender and the recipient, saving energy and minimizing channel effects on data.	It involves combining multiple levels of security measures to create a robust and reliable computing environment.	Scalability, Accuracy and reliability issues can arise due to computational limitations, memory constraints, or the need for high-speed processing.
WDFAD-DBR[7]	This protocol succeeds in reducing energy tax, enhancing PDR, and reducing packet drop at the expense of E2ED.	By examining additional neighbor data, characteristics of the channel, including depth and leftover energy with a high node density, duplicate packets are decreased.	By allocating frequencies dynamically based on the network conditions, It contributes to reducing energy use and extending network lifespan.	The protocol may not accurately estimate the energy requirements of the network, leading to suboptimal energy utilization.
HH-VBF[35]	The performance of the network is measured using two measures. According to simulation results, the AHH-VBF routing protocol performs better than HH-VBF in terms of dependability, energy	It can change the forwarding range hop by hop in keeping with the distribution of neighbor nodes.	HH-VBF facilitates the scalability of the network by dividing it into multiple levels..	The HH-VBF protocol introduces additional latency in data transmission. The process of virtual sinking and hidden node avoidance

	efficiency, and end-to-end delay.			requires extra communication overhead and coordination.
H2-DAB[26]	When a sensor node needs to transmit data to a destination node, it first broadcasts the data along with its temporary address to its neighboring nodes.	Once a node has obtained its address, it can participate in routing data packets within the network.	H2-DAB enhances routing efficiency in UWSNs.	As the number of sensor nodes increases, the management and coordination of dynamic addresses become more complex.
MATLAB[16]	MATLAB has extensive signal processing functions and toolboxes that can be used to process the signals received from underwater sensors.	MATLAB enables to design and evaluate various communication protocols for UWSNs..	It offers built-in functions, libraries, and toolboxes specifically designed for signal processing, communications, and underwater acoustics.	UWSNs typically involve specialized underwater acoustic modems, sensors, and other hardware.
TORA[43]	It is a routing protocol to establish and maintain multiple routes Among the nodes at the source and destination in a dynamic and self-adaptive manner.	When origin node needs to transfer a packet to the desired node, it broadcasts a "Route Request" (RREQ) message to its neighboring nodes.	It is able to quickly adjust to environmental changes underwater, such as node failures, link quality variations, and topology changes.	TORA assumes that nodes are mobile, which may not always be the case in UWSNs.
TM2RP[28]	It is a time-multiplexed protocol that utilizes two different routes to transmit data from source to destination.	The protocol works by dividing time into slots and allocating these slots to different nodes in the network..	TM2RP reduces the communication latency in UWSNs by concurrently performing medium access control and	The main challenge in UWSNs is the limited region of communication and the

	The two routes are known as the primary route and the alternate route.		routing.	characteristics of the underwater channel, which includes increase propagation delays,
2H-ACK[22]	The 2H-ACK protocol is intended to increase the data transmission's dependability in UWSNs by introducing a two-hop acknowledgment mechanism	The intermediate nodes receive the data packets and perform error checking and data processing.	The 2H-ACK protocol improves reliability by allowing a packet to be acknowledged by a two-hop neighbor, thereby increasing the chances of successful transmission acknowledgment.	In UWSNs, where energy is a limited resource, this can significantly affect the network lifetime.
DM-DBR[9]	It aims to mitigate the effects of underwater acoustic channel characteristics, such as long propagation delays, limited bandwidth, and high error rates.	Once the channel is selected, the DM-DBR mechanism allocates the available bandwidth among the sensor nodes. This allocation can be done dynamically to adapt to changing network conditions.	DM-DBR can provide high bandwidth communication, allowing for the transmission of large amounts of data in UWSNs.	The protocol may struggle to handle high data rates or large-scale deployments, resulting in decreased network performance.
E2-LR[46]	Manages needless flooding of hello packets. In addition, E2LR evaluates minimizing the process's end-to-end latency and regularly updating the energy status.	The protocol may utilize adaptive routing algorithms that dynamically select the most energy-efficient and reliable paths based on current network conditions	The protocol can extend the network's overall lifetime and enhance network sustainability.	This can result in increased network overhead, which consumes valuable network resources and bandwidth.

2.4 Research Gaps and Directions

Underwater Wireless Sensor Networks (UWSNs) are a specialized type of wireless sensor network that operate in underwater environments. While significant progress has been made in UWSN research, there are still several research gaps and directions that can be explored to further advance the field. Here are a few:

- **Energy Efficiency:** Energy conservation is crucial for UWSNs due to the limited and non-rechargeable battery resources of underwater nodes. Research can focus on developing energy-efficient protocols and techniques for UWSNs, including energy harvesting mechanisms, duty cycling, and energy-aware routing algorithms.H2-DAB [26] and 2H-ACK [27] uses same node all the time which can decrease its energy efficiency.

- **Addressing Scheme:** Each node maintains a routing table that maps destination addresses to the next hop or interface to reach that destination.H2-DAB [26] uses addressing scheme but its address does not work more than 9 Layers. So we have to improve is addressing scheme.

- **Network lifetime:** H2-DAB [26] and 2H-ACK [27] only forwards data based on the node id addressing scheme and does not consider energy as a metric to forward the data. As a result, it has less network lifetime because it always forwards the data to the same node. We have to increase the network lifetime.

Various schemes have been brought out with the intention of offering UWSN routing that is reliable and efficient. In routing protocols of this type, energy consumption, performance, throughput, network lifetime, and end-to-end delay are considered critical design factors. Numerous studies have been conducted on energy and delay efficiency, which accounts for stable data transfer between sensor nodes and longer network lifetimes. The goal of this research is to suggest scalable addressing systems and energy-efficient routing that can improve the reliability of data transmission based on the previously described results. Minimize packet loss and efficiently utilize node energy to cut down on the quantity of network updates. Additionally, it ought to lengthen the network's lifespan and increase its effectiveness.

2.5 Summary

The latest routing techniques utilized in UWSN have been thoroughly examined in chapter 2. Studying current routing methods found in the literature is the main objective of this chapter. We have done a critical analysis of the routing schemes. Several routing algorithms have been compared based on factors such as packet delivery ratio, delay, energy economy, and network lifetime. Additionally, the workings, advantages, and disadvantages of the schemes have been shown in tabular form for comparison. Additionally, topics for future research have been mentioned, as well as research gaps in previous research.

CHAPTER 3

METHODOLOGY

3.1 Overview

An improved Addressing Based Energy-Efficient Routing (AEER) for UWSN-based is designed and developed in this chapter using a research technique. The primary objective of this study is to provide a technique for increasing energy effectiveness and improving the network's addressing scheme. The scheme attempts to create an effective routing with end-to-end delay and network lifetime in an underwater environment. Additionally, a method is used to reduce the frequency of network updates, hence improving energy efficiency. With the intention of lowering energy usage, decreasing end-to-end latency, and increasing network lifetime, the Addressing based Energy-Efficient Routing (AEER) protocol is presented. Consequently, the research approach described in this chapter is regarded as a first step that gives the steps taken a direction to achieve set targets.

3.2 Operational Framework

The AEER protocol being proposed aims to enable effective routing in UWSNs.This plan intends to enhance packet delivery ratio and cut significantly the energy used by sensors to forward data. In order to conserve energy, unwanted network updates are minimized. Additionally, a technique for scalable addressing and energy conservation is applied to address low packet delivery and decreased packet loss. This strategy can improve upon the drawbacks of the current methodology employed in UWSN for monitoring apps. As shown in Figure 3.1, this operational framework consists of three phases. The development of an energy- and delay-efficient data forwarding mechanism is the main focus of this research. Evaluating current plans and finding challenges make up the first part. The second step consists of developing a scalable addressing scheme based on identified issues in existing protocols and Lastly, The suggested protocol's performance is assessed against cutting-edge routing protocols in the framework's third phase, which is performance evaluation and evaluating the performance of developed protocols against benchmark schemes.

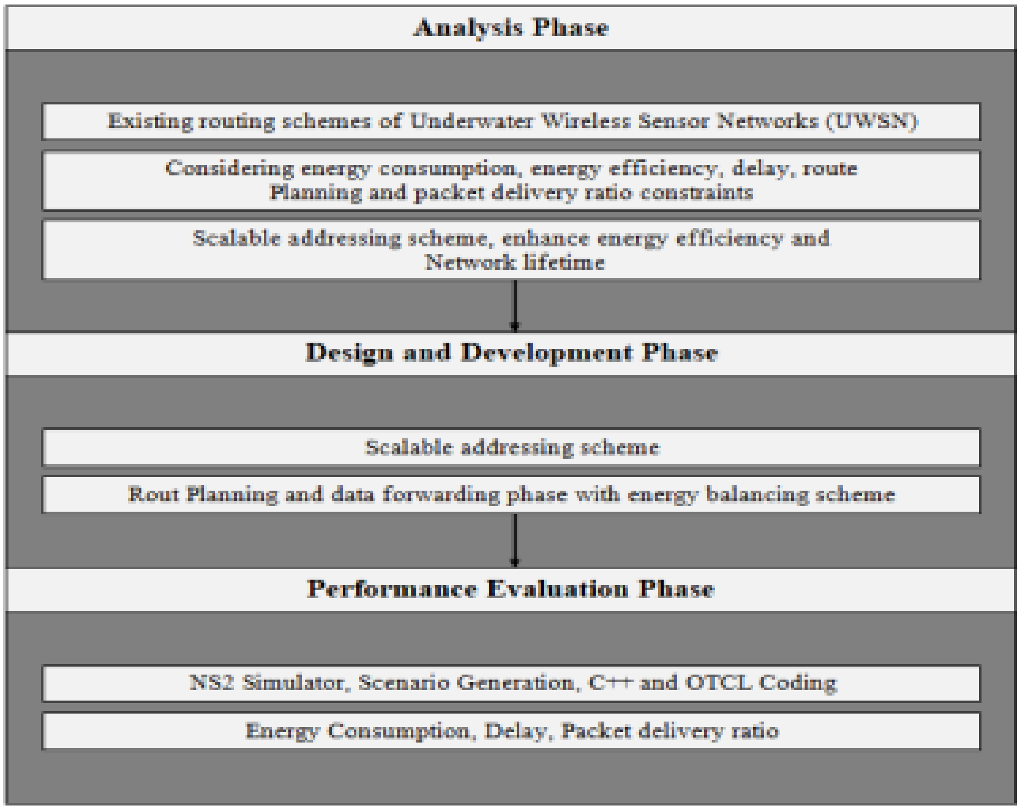


Figure 3.1: Operational Framework of the Research

3.3 Research Design and Development

This article will discuss the process of designing and developing the AEER protocol, which includes the following stages: Rout planning, scalable addressing scheme and data forwarding phase with energy balanced scheme.

3.3.1 Step 1: Rout planning

Designing effective routes for data transmission over a network of underwater sensors is the goal of route planning in an Underwater Wireless Sensor Network (UWSN). Route design in UWSNs demands considerable thought due to the distinctive difficulties of underwater environments, including constrained bandwidth, changeable communication circumstances, and energy limitations. As we mentioned in our problem statement, we are looking at an application for field monitoring, where samples of data are typically needed on occasion. In order to conserve energy, nodes can sense and send data in a brief period of time during one interval, at which point they can either sleep or turn off their transceiver until the next sampling interval. When the lifetime exceeds the threshold value, the HopIDs will be reset to "99" across the network and their value will be adjusted correspondingly. New IDs will then be assigned with the help of fresh Hello packets, and the procedure will be repeated. Any node that has to send packets before the HopID expires will wait until it has a fresh HopID before sending those packets. By obtaining the new HopIDs in this manner, nodes will receive new IDs the following time that correspond to their new positions, which helps to address the issue of even slight vertical movements. We are focusing on energy efficiency as well as routing because the routing is done on the basis of energy and their ID’s.

3.3.2 Step 2: Scalable Addressing Scheme

To efficiently organize and route data in a network that may include a large number of underwater sensors deployed in aquatic environments, such as seas, lakes, or rivers, an Underwater Wireless Sensor Network (UWSN) needs to have a scalable addressing scheme. Due to the severe and unpredictably underwater circumstances that might impair communication and sensor deployment, UWSNs present particular difficulties. There will be two types of addresses for each surface sink:

- Sink ID: Each sink has a distinct ID that Hello packets use to identify the sink. DestID is a static ID of "0" that is shared by all sinks. This ID will be used across all data packets as the Destination ID.
  Apart from anchored nodes, sensor nodes will use two other sorts of addresses.

- Node ID: a special ID allocated only for floating nodes, which aids in identifying the nodes when inquiries and data packets are forwarded.

- HopID: Dynamic HopIDs will be used by floating nodes. Each node has this highest value as the default HopID before receiving the Hello Packets, and it can go up to "99" before repeating the procedure. It will update its new HopID based on its locations after receiving the Hello packets.The underwater layer model on which current research is in progress is presented in Figure 3.2.

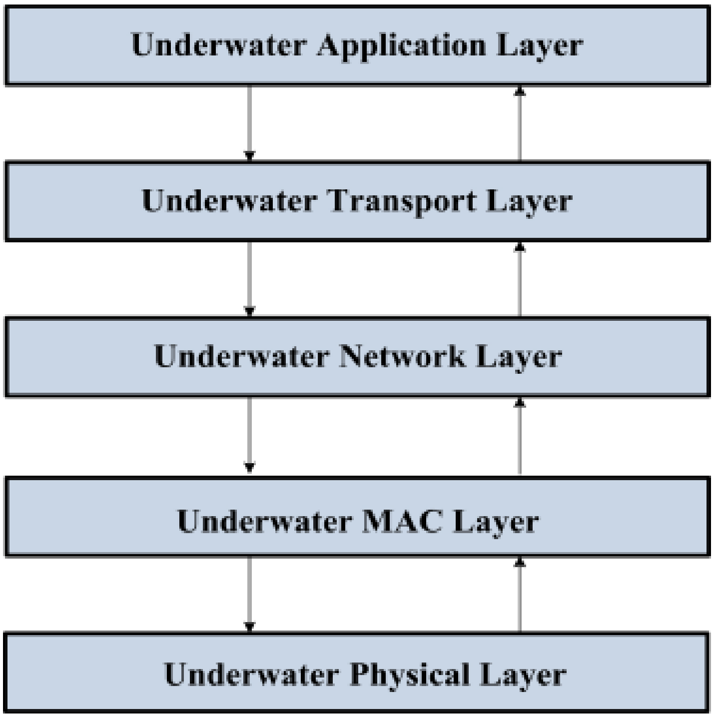


Figure 3.2: Underwater Layer Model [47]

Although all work done through network layer and data link layer we will not use physical layer at any level.

3.3.3 Step 3: Data forwarding with energy balancing Phase

In order to achieve a longer network lifetime, energy balancing is an essential requirement. The chosen node uses energy to process, receive, and send the data packet when a source chooses one of its one-hop neighbors. As a result, as each data packet is processed and forwarded, its energy reduces. As a result, an energy balancing strategy is needed to prevent the use of the same node repeatedly. Due to this, H2-DAB has a limited network lifetime. Use the following hop's available nodes alternately even within a set period of time to lessen the likelihood of a communication gap. To address this issue, AEER offers a new technique for keeping the source node informed of the hop neighbors' residual energy information.

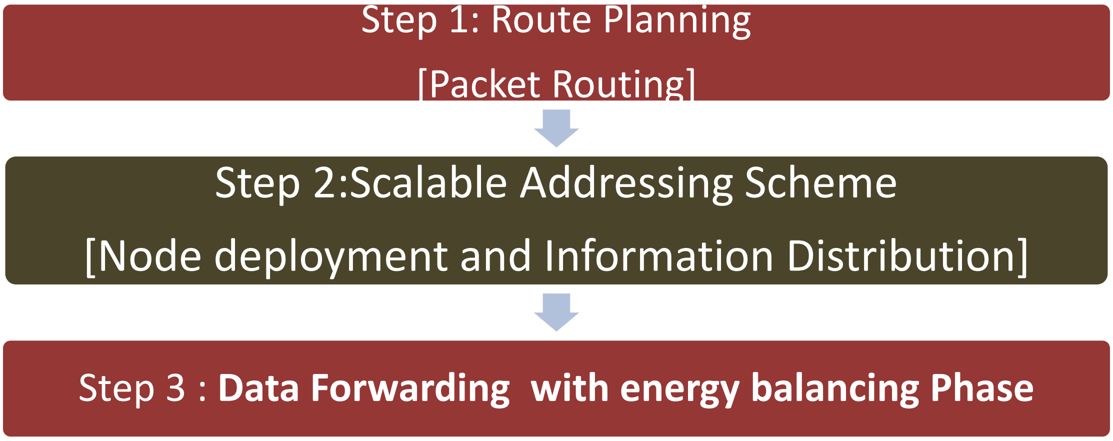


Figure 3.3: Steps in Proposed Methodology

3.4 Simulation Framework

We used the NS-2 tool, which is an ordinary network simulator (version 2), to assess the performance of the proposed protocol. An event-driven tool that effectively simulates communication networks is called NS-2. In the NS-2 simulation, the frontend is handled by OTcl and the backend is handled by C++. Through TclCL, C++ and OTcl are linked together. Following simulation, network animator (NAM) and XGraph receive the trace file generated by TCL to produce results [59]. Table 3.1 illustrates the AEER simulation environment 3D area 1500m x 1500m x 1500m network area is the size of the network scenario as determined for simulation purposes. In the network, a maximum of 400 sensor nodes are employed. In the middle, where its motion is predetermined, is a moveable sink. Moreover, Table 3.1 defines the simulation parameters. The simulation procedure begins after all the simulation settings have been set up to test the suggested AEER protocol. The AEER protocol is compared to related schemes like H2-DAB and 2H-ACK in order to assess its performance. We illustrate the simulation results of our proposed AEER scheme while comparing them with those of the typical H2-DAB approach. With deploying nodes in the network, our proposed approach produced improved results. For example, when there are fewer nodes, delivery ratios decrease more quickly when we use AEER than when we use the H2-DAB method. Because UWSNs are error-prone and nodes can die or quit the network, causing the network to be sparse, the AEER protocol performs better in these circumstances with low concentration. Routing time is depending on how much nodes are there on the way to deliver a packet. It would take approximately 6.512 milliseconds to travel from one node to another.

Table 3.1: Simulation Parameters

Parameters Description	**Values**
Network sensor field	$1500m \times 1500m \times 1500m$
Number of nodes	$50 - 400$
MAC Protocol	IEEE 802.15.4
Speed of mobile sink	$10m/s$
Sink Mobility pattern	Random
Data packet size	512 bits
Channel Type	Wireless
Initial energy	$100J$
Simulation Time	$100s$
Transfer Rate	$250\ kb/s$
Sending Energy	1.4 W
Receiving Energy	1.0 W

3.4.1 Performance Metrics

For assessing the productivity and efficiency of various systems, processes, or technology, performance metrics are essential. Several significant performance metrics have been used in the context of networking, especially Underwater Wireless Sensor Networks (UWSNs), to evaluate the integrity and usefulness of the network. Network administrators, researchers, and engineers can use these metrics to determine how well the network is functioning and whether its objectives are being attained. The routing protocol is one of the main technologies of the underwater wireless sensor network, which is used to determine an efficient way from the node of origin to the node of destination and send the data information accurately along the chosen path. Establishing an effective energy path, maximizing network longevity, enhancing fault tolerance of the route, and creating a dependable data forwarding mechanism are the key goals of designing a wireless sensor network routing protocol. The following criteria are frequently used to assess the performance of routing protocols: accuracy, routing overhead, energy efficiency, resilience, and QoSrequirements. The most fundamental requirements of the route is the accurate and secure delivery of data to the destination. While this is happening, reducing routing overhead and balancing energy use can maximize the lifetime of the network.[4]

The underwater acoustic channel transmits data at a rate that is five orders of magnitude slower than the terrestrial radio channel. The transmission of links between nodes is also quite unreliable due to numerous interferences. Therefore, one of the key design principles for the protocol is to minimize end-to-end delay. The smallest amount of time (including propagation, transmission, holding, processing, and queuing delays) necessary for a packet to be successfully received from the source node to the destination node is known as end-to-end latency. Only data packets that reached their destination successfully are counted.[4]

The protocol's performance is assessed in simulation using the following metrics:

i. **Packet Delivery Ratio** The transfer of the data packet is the primary task of developing a path. In order to transmit data packets from the source node to the destination node with the least amount of network cost, the routing protocols are primarily in charge of creating and maintaining the data transmission path. The ratio of the number of data packets that are successfully delivered to the destination nodes to the total number of data packets created at the source nodes is known as the packet delivery rate (PDR).[4]

(pdr): referred to as the ratio of packets transmitted by the source to packets successfully received at the destination. Equation 3.1 [56] below provides it:

$$pdr = \frac{no.of packets received}{no.of packets transmitted} = \frac{\sum P_r}{\sum P_{tr}} \qquad (3.1)$$

ii. The average **delay** time a data packet takes to travel from its source to its destination is known as the delay. Equation 3.2 [57] below provides it:

iii.

$$delay = \frac{total\ delay\ time}{no.of\ packets\ sent} = \frac{\sum_{i=0}^{n} (T_{ri} - T_{si})}{\sum P_n} \qquad (3.2)$$

'T_{ri}' is packet reception time 'T_{si}' is packet transmission time, and 'i' is packet identifier.

iv. The quantity of **energy** used by nodes during data transmission is known as energy consumption. It can be computed as the difference between the sensor nodes' initial energy (Ei) and final energy (Ef). Equation 3.3 [58] can be used to calculate it.

$$E = \sum_{j=0}^{n} \left(Ei_j - Ef_j \right) \qquad (3.3)$$

v. **Network lifetime**, which measures the amount of time from network initialization to the point at which the energy of the first node is fully depleted, is inversely related to the energy consumed by nodes.

Some classic underwater routing protocols that have not been discussed in detail in the chapter's full description will also be compared as part of the performance comparison analysis. The performance analysis indicators employed in this study are also compatible with the results that have been provided in the various types of literature because of the confined experimental environment. Additionally, the measurement range differs significantly due to the variable testing environment. We can only provide an up-to-date comparison.[4]

a) Energy Based Routing Protocols

In wireless sensor networks, where sensor nodes are frequently powered by batteries with a limited capacity, energy conservation is of most importance. When these batteries run out, nodes stop functioning and could potentially cause a network outage. By effectively utilizing the energy resources available to each node, energy-based routing techniques seek to increase the network's lifespan. These protocols decide which data packets should be routed along energy-efficient channels, minimizing energy consumption differences between nodes and extending network functioning as a whole. Routing considerations made by energy-based routing protocols take into account energy-related parameters of individual nodes and network links. Node battery voltage, remaining energy, and energy consumption rates are typical measurements. The protocol favors pathways made up of nodes with greater energy reserves or lower rates of energy consumption when choosing a path for data transmission. This routing technique reduces the possibility of a few crucial nodes' energy being prematurely depleted, which could result in network dispersion or coverage loss. In wireless sensor networks, energy-based routing protocols are essential tools for controlling the energy resources of sensor nodes. These protocols are crucial for a variety of applications, including underwater sensor networks, environmental monitoring, and industrial automation, as they assist lengthen network lives, improve dependability, and assure sustainable operation. These procedures are still being developed and improved by scientists and engineers to address the unique difficulties presented by varied deployment scenarios and environments.

b) Data based Routing Protocols

In existing wireless sensor networks (WSNs) and other distributed systems where effective data transmission is a top priority, data-based routing methods play an essential role. Data-based routing systems, in contrast to conventional routing protocols, base routing decisions on the properties of the transmitted data rather than considerations like hop count or network structure. These protocols are especially helpful in applications where the content, quality, or relevancy of the data is more important than just getting it from one place to another. Data-based routing protocols base their routing decisions on the characteristics or content of the data packets. They might consider things like data priority, data kind (such text, image, or sensor signals), and data freshness. These protocols might then transport important or time-sensitive data in a different way than less significant or delay-tolerant data. Networks are better able to satisfy application-specific requirements. In many applications, including as multimedia streaming, telemedicine, and industrial automation, data-based routing protocols are essential to achieving desirable QoS levels. These protocols have the ability to give priority to routes that satisfy particular QoS requirements, such as low latency, high throughput, or little packet loss. Data-based routing protocols excel at delivering the requisite performance in cases where strict QoS guarantees are required. Overall, data-based routing protocols are crucial in modern WSNs and distributed systems, where the relevance, quality, and substance of data are crucial. These protocols give network managers and application designers the ability to customize routing choices to the particular requirements of their applications, improving the overall efficacy and efficiency of data transmission in these networks. The significance of data-based routing protocols is likely to keep increasing as technology develops and applications become more data-driven.

- ## Network Simulator 2

A widely used open-source network simulation software known as NS2 (Network Simulator 2) is especially popular in the academic and research circles. The performance of different networking protocols and systems can be modeled, simulated, and analyzed using the platform it offers. Because NS2 is so flexible and extendable, researchers can quickly create and use unique protocols and algorithms. This adaptability is useful for developing fresh thoughts, testing cutting-edge networking theories, and customizing simulations to meet particular research requirements. Apart from ad hoc networks, sensor networks, wired and wireless networks, and other networking technologies and protocols are supported for modeling. It is ideal for analyzing and modeling various network scenarios because of its adaptability. Through small-scale environments to large-scale networks with thousands of nodes, NS2 can simulate networks of different sizes. This scalability is essential for researching how networks behave at various scales.

It offers visualization tools to aid researchers in studying the outcomes of simulations. In order to facilitate data analysis and presentation, it provides tools for creating graphs, charts, and animations to show network performance measures.

3.4.2 Assumptions and Limitations

The following assumptions and limitations are taken into consideration while simulated:

- The sink is initially positioned in its center, with nodes surrounding it; the sink is then free to move within a specific region of the network. The inquiry request and inquiry reply messages result in a significant end-to-end delay in the data transfer process in a network that is already delay-constrained.

- It may be that this sender hopID parameter is used to force the next hop node to respond. If so, Hop ID itself is insufficient for the successive hop node to identify the original source node. Rather, Hop ID represents the layer that the source is situated on, and many nodes with the same hop ID on the same layer are accessible.

- When the nodes have consumed up all of their energy, they have been declared dead.

3.5 Addressing Based Energy Efficient Routing (AEER)

A routing scheme For UWSN-based application, AEER has been suggested as a solution to the limitations of current protocols. The proposed architecture attempts to boost network performance by offering dependable and energy-efficient routing. The aim is to enhance the network lifespan and the addressing system. Additionally, by predicting energy efficiency, which takes into consideration an increased packet delivery ratio and end-to-end delay, the network's reliability is increased. The following steps in this plan are covered in more depth below.

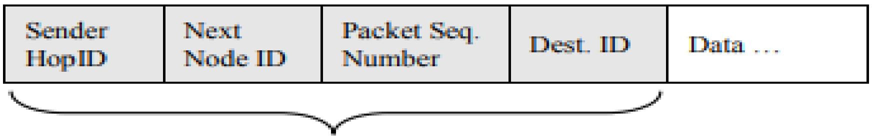
3.5.1 Improved Energy Lifetime

The proposed solution in this research has increased network energy lifetime. Figure 3.3 shows how to send a data packet towards next node. He figure shows the source node as N7 and it’s own HopID is 76 will send an inquiry request among its neighbors nodes and will check their HopIDs. This source node will contain node ID of he nodes which will request. The inquiry reply will have two fields one will be node ID and other will be HopID. All he neighboring nodes within the communication range will reply to source node. In the figure the nodes N4,N6,N8 and N9 are replying to source nodes with their node IDs and Hop IDs. Every node will have its own weights and energy which will also be send to source node in reply to inquiry. The source node will response to the node whose energy will be highest.Selection is based on its id and its corresponding energy.From the figure 3.3 two replying nodes N4 and N6 and the maximum energy is of N6 among all replying nodes so the source node will consider node N6 as next Hop and send data packet to that node. There is no deficulty to get node id 80 or so on it depends on it’s neighbours.There is no clustering included in this scheme.No time is required to selecting the best node because information is already stored in routing table.The formula used to calculate energy is shown in equation (3.4)

$$w2 \times \left(1 - \frac{\mathrm{Er.Ni}}{\mathrm{Et}}\right) \qquad (3.4)$$

Where E_T =Total Energy and Er. Ni = Remaining Energy of Node

From this scheme it is cleared that the network energy life time is increasing as the source node is replying to the node with highest energy.



Sender HopID	Next Node ID	Packet Seq. Number	Dest. ID	Data ...

Figure 3.4 Data Packet Format [26]

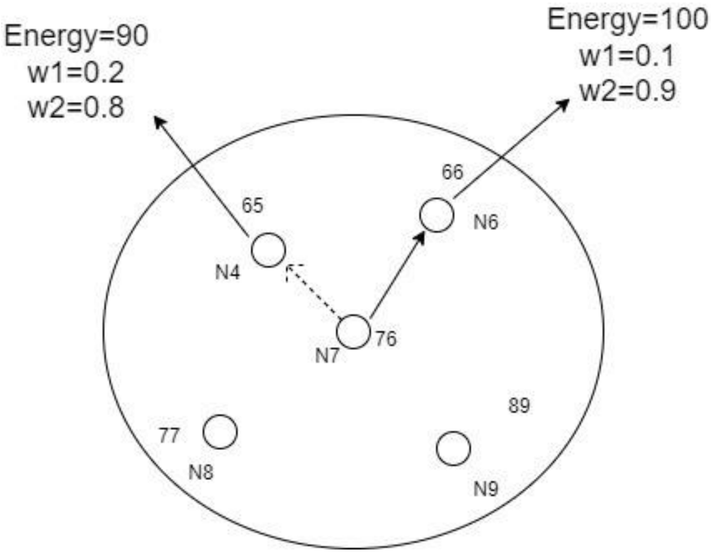


Figure 3.5 Selection of Next Hop on energy basis

3.5.2 Improved Addressing Scheme

At the sink the addresses of the nodes will be started from 000.The right bits represent the nodes and their respective layers and left most bit represents a flag bit.

We will have attached two flag bits (0,1) Alternatively. The right 8 bits representing 2 decimal numbers will update them according to the layers and nodes getting data packet and the left flag bit will remain 0. After the 9th layer bits will reset to 1 and flag bit will become 1. This will iterate the 9 layer addressing scheme again and after this iteration. Now we have approached to 18 layers. After wards the right bits will again reset to 1 and flag bit will become 0. This process will continue until the destination address is reached which is 000.Floating node will remain 99 as they have not received any hello packet. When a node receives a packet directly from a sink it will updated as 19 and when it receives packets from any other sink it will updated as 11. We have attached flag bit with floating node to extend addressing beyond 9 layers. After 9 layers flag bit will be updated as 1 and addressing will remain same.

However, after nine layers, the flag bit becomes 1 while the process of updating the rest of the ID’s continues. When a node comes from another sink, its ID is updated by hop of the distance. When the 18th layer is reached, the flag bit will reset to 0 and the process will continue to its destination.if there are 50 nodes its energy depends on the route which we have seleced. In this way, a loop continues and its layers are extended and IDs are updated. Developing and using routing protocols that minimize energy consumption by optimizing paths and reducing the number of transmissions.

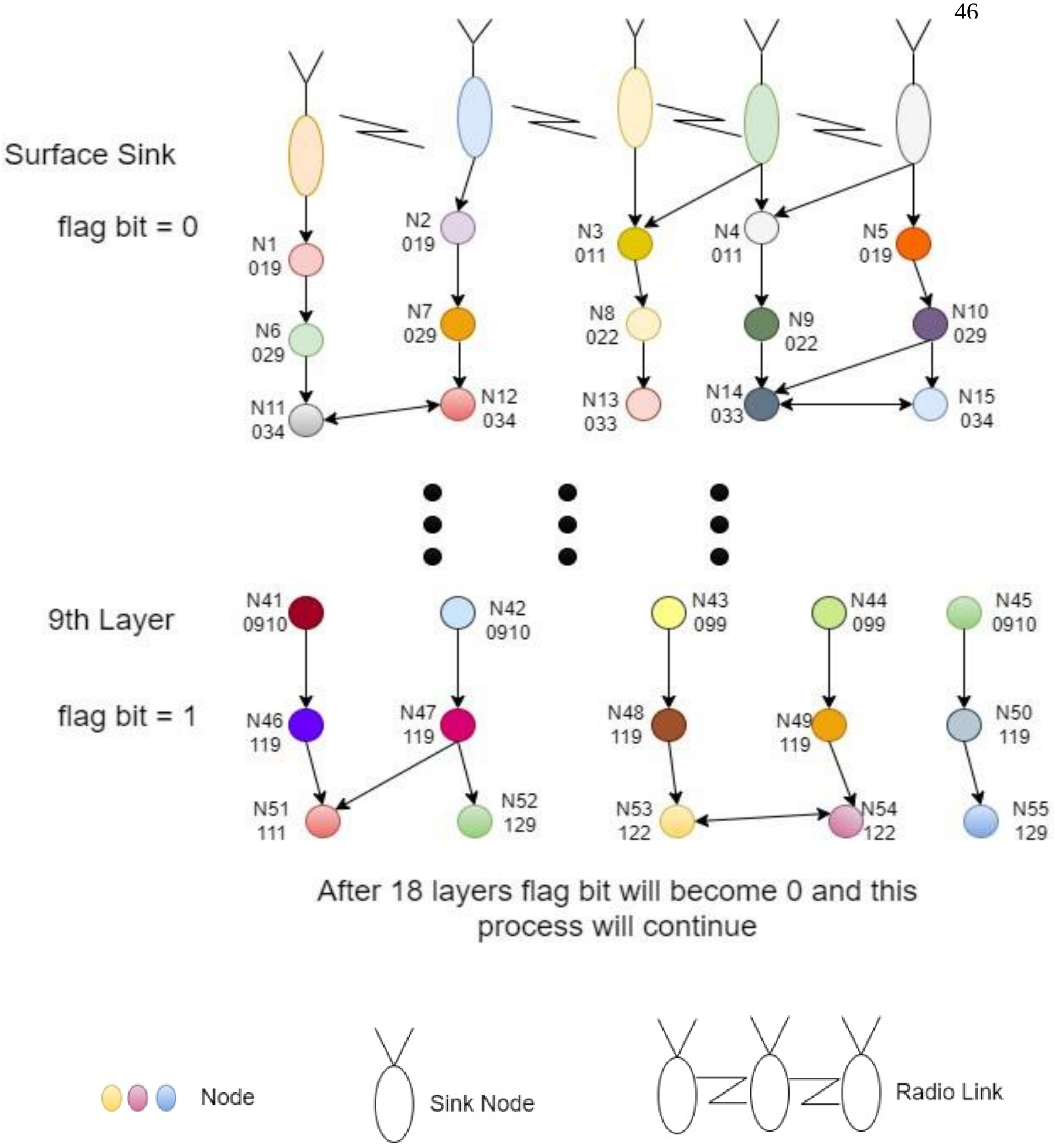


Figure 3.6 Assigning HopID’s with the help of Hello Packets

3.6 Summary

This chapter addresses the issues with the existing routing protocol and provides a solution for the proposed protocol to fix these issues. Also presented with an operational framework that illustrates the basics of the flow of the proposed methodology. Furthermore, figures are used to explain each stage of the procedure. There are several strategies presented to address a particular issue. Moreover, this section provides a brief explanation of the procedures in the proposed protocol, including assigning hop id's, evaluating energy lifetimes, and packet routing throughout the data forwarding phase.

CHAPTER NO 4

PERFORMANCE EVALUATION OF AEER

4.1 Overview

A comprehensive evaluation of the simulation results and conclusions to evaluate the proposed protocol (AEER) is presented in Chapter 4. Here is also a comparative analysis with other recent protocols taking into consideration different performance parameters.

4.2 Results and analysis

To evaluate the performance and effectiveness of AEER, Packet Delivery Ratio, Energy Consumption, End-to-End Delay, and Network Lifetime are taken into account as evaluation factors. These measurements come from procedures that are similar, including 2H-ACK and H2-DAB. Additionally, a comparative study of various treatments is provided in this section. A graphical representation of the metrics' results is also provided.

Moreover, the metrics are analyzed with different numbers of nodes. The H2-DAB and 2H-ACK protocols generated identical values for the nodes used in this experiment. This is required to track how nodes affect the protocol's performance. Because of the uncontrolled flooding of route request packets and parallel transmissions, the increased number of nodes in H2-DAB has ended up resulting in increased energy usage. The network lifetime is consequently shortened by these energy depletions. Consequently, it is essential to assess the AEER protocol with different numbers of nodes in order to investigate the behavioral impact of these nodes on the protocol's performance.

4.3 Performance Comparison with related Schemes

This section evaluates the performance of the proposed AEER protocol by comparing it with two benchmark protocols, respectively the H2-DAB[26] and 2H-ACK[48] routing-based geographic protocols.

H2-DAB does not require extensive routing table regular consumption, trained hardware, or full dimensional location data. Because the UWSN's available data rates are so low, H2-DAB made an effort to maintain less routing overhead as possible. In order to meet underwater requirements, H2-DAB uses the concept of per contact routing rather than source routing or per-hop routing. A key feature of the H2 -DAB is that the delivery ratios are not dependent on the density or sparsity of sensor nodes [26].The 2H-ACK protocol involves two nodes keeping an identical duplicate of a packet of data. Data packets created at any point in the network typically need a maximum of 5-7 hops to reach their destination in an underwater environment. In these circumstances, the 2H-ACK system not only manages the packet losses but also supports in reducing network congestion without adding to its currently existing workload [48].Furthermore, a technique for balancing energy is also used in the proposed approach to avoid network collisions. Consequently, in this study, the simulation results of AEER are compared with the abovementioned schemes. The network structure and performance measures implemented are the same as those in H2-DAB. While the node values and simulation parameters are taken from H2-DAB and H2-ACK, respectively.

4.3.1 Packet Delivery Ratio

The packet delivery ratio outcomes for AEER, H2-DAB, 2H-ACK and E2LR are shown in Figure 4.1, which also shows the effect of node count. As can be seen from the graph, H2-DAB has a high PDR of 88.5% while having a relatively small number of nodes at 125. Since H2-DAB chooses its next hop from among its neighbors, more nodes are available for data forwarding. This routing method is based on HOP by HOP routing. However, because 2H-ACK uses the shortest link while forwarding data, it achieves a PDR of 89%. Moreover E2LR has a PDR of 92% .Figure illustrates how PDR for H2-DAB rises to 97% and progressively rises as the number of nodes grows. The transmission of the source and destination nodes is the cause of this increase. However, when there are a smaller number of nodes, AEER gets a better PDR of about 90%, but when there are more nodes, it reaches 98.5%. This is due to the fact that AEER uses a cost function to pick routes that are dependable for data forwarding. While E2LR uses all of its criteria to give links of high quality and gets highest PDR of 99.E2-LR checks link quality which significantly lowers the overhead of packet loss and retransmissions. As an outcome, the proposed AEER protocol works better than both since it increases packet delivery ratios by 15% and 20% higher than H2-DAB and 2H-ACK and 10% less than E2LR, respectively.

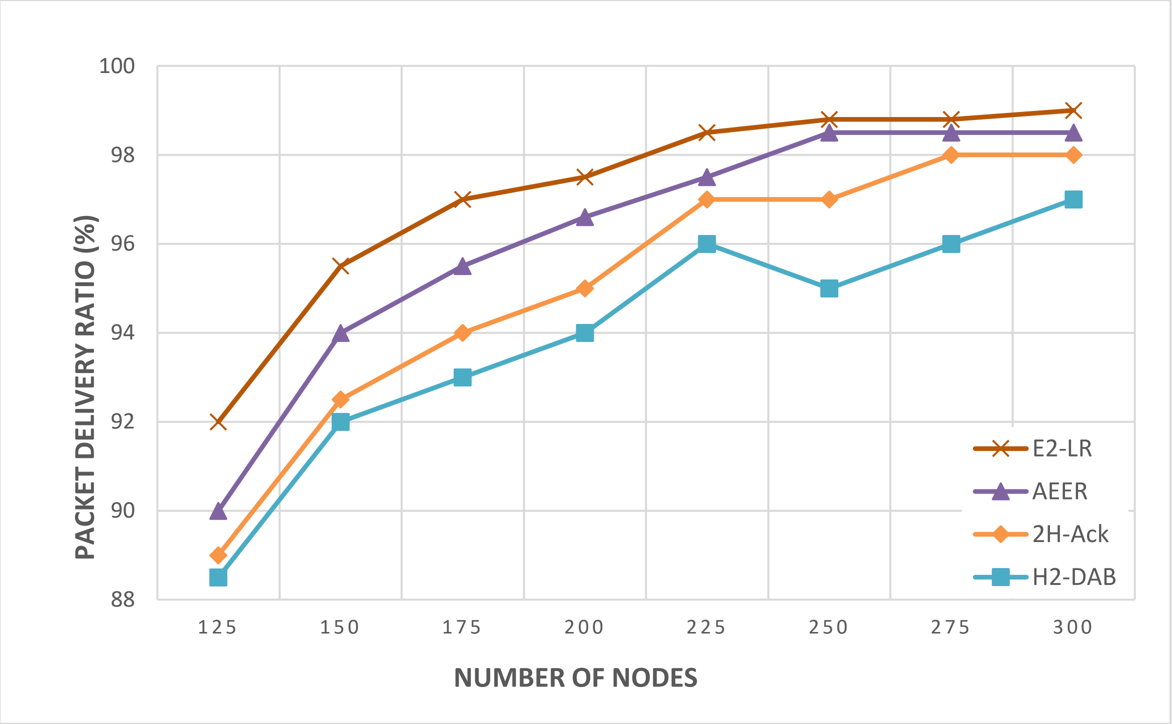


Figure 4.1: Effect of Packet Delivery Ratio on different schemes

4.3.2 Energy Consumption

Figure 4.2 shows the energy consumption results for each of the four schemes AEER, E2LR, H2-DAB, and 2H-ACK as a function of nodes. In H2-DAB, as the source transmits packets until the destination responds, the flooding of network request packets during the route discovery process results in additional energy overheads. According to the figure, as the number of nodes in H2-DAB increases, correspondingly rises the nodes' consumption of energy. Energy updates in the network as a whole grow with the number of nodes, increasing collisions and decreasing the network's energy efficiency. In contrast to the H2-DAB protocol, there are somewhat fewer energy losses in the 2H-ACK and E2LR protocols. since choosing the shortest path for data transmission is a part of it. However, although AEER uses less energy than E2LR, H2-DAB, and 2H-ACK protocols, it performs better. The following factors are mostly responsible for this. First, in order to enable each node to be aware of the data from previous nodes, hello packets are broadcast rather than needlessly consuming the network with route request packets. Secondly, it utilizes a cost function to determine the best next-hop for data forwarding. By placing a threshold on pointless updates, it lessens the energy consumption caused by path updates. The choice of a route also takes into account the link quality value, which insures the reliability of the paths linking the nodes. Figure 4.2 illustrates that there is only an 8% difference in energy consumption between AEER and E2LR. But AEER significantly reduced energy consumption by 12% and 10% less for the H2-DAB and 2H-ACK, respectively. Thus, it has been proven that AEER outperforms alternative routing protocols with respect to energy consumption.

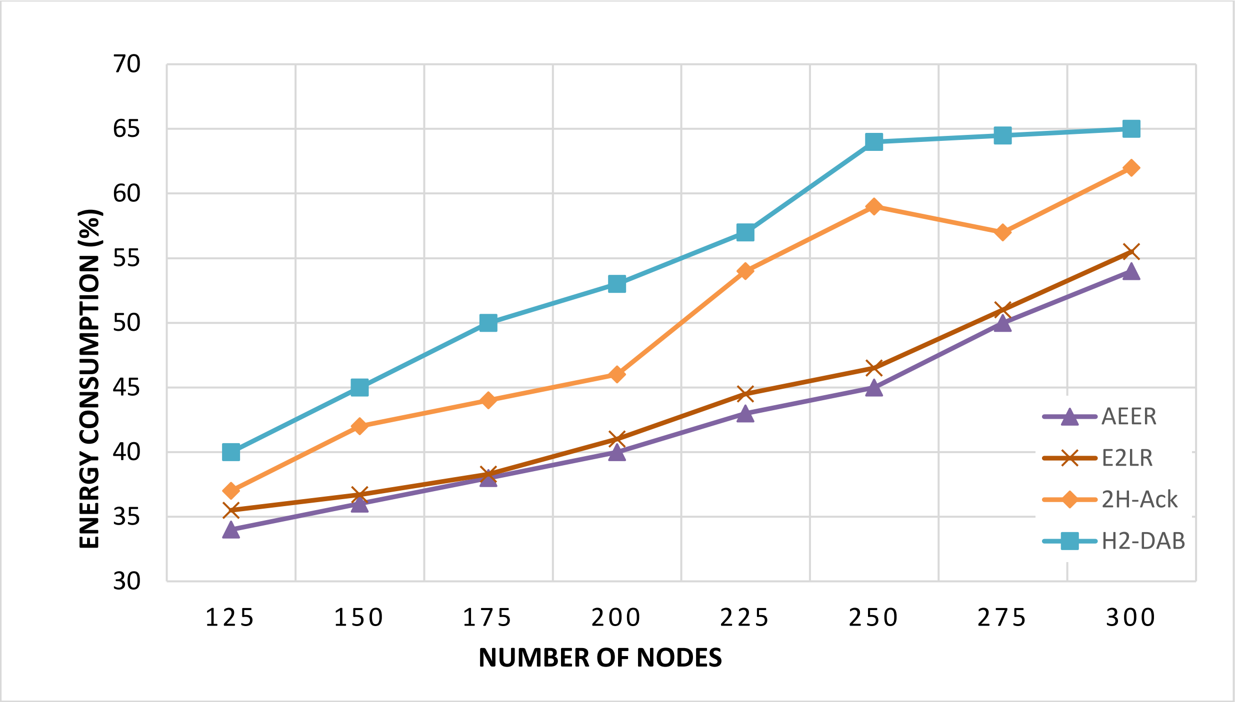


Figure 4.2: Effect of energy consumption on different schemes

4.3.3 Network Lifetime

Network lifetime is the most important factor to consider when evaluating a network's performance because longer networks perform better. The performance of four protocols H2-DAB, 2H-ACK, E2LR and AEER is represented in Figure 4.3 in relation to network lifetime. Due to the dynamic structure of the nodes, H2-DAB has a short network lifetime because the same node is used frequently, thereby consuming energy. The probability of retransmissions raises due to the simultaneous data transmissions, which enhances the node's energy consumption. Poor network lifetime is the result of the lack of an energy balancing mechanism that overcomes this. Conversely, AEER and E2LR have longer network lifetimes than H2-DAB and 2H-ACK**.**On the basis of the neighbors' smallest hop id's, 2H-ACKdetermines the next hop id.Energy lifetime is decreased since it always uses the shortest hop id's.On the other hand, Through AEER a single cost function is used to figure out the next-hop node based on the weighted values of two parameters: energy and weights. Accurate and effective route selection can be supported by the addition of several parameters and a weighted cost function. Moreover, threshold-based methodologies are created for compensating for nodes' energy imbalance and prevent unwanted energy losses. Thus, the results indicate that AEER improves E2LR, H2-DAB and 2H-ACK in terms of network lifetime by 10%, 15% and 20%, respectively.

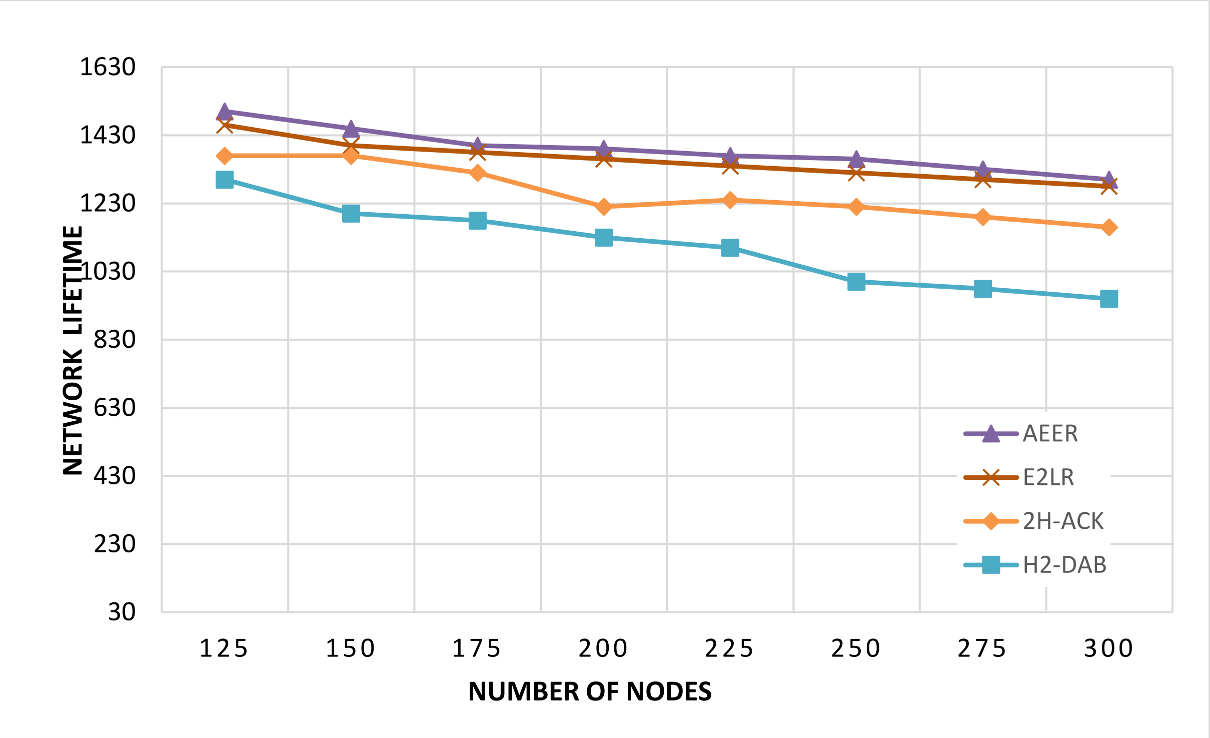


Figure 4.3: Effect of Network Lifetime on different schemes

Table 4.1: Comparative analysis of different protocols

	Packet Delivery Ratio(PDR)	**Energy Consumption**	**Network Lifetime**
Proposed Protocol(AEER)	98.5%	54%	25%
E2-LR	99%	55%	10%
2H-ACK	98%	62%	20%
H2-DAB	97%	65%	15%

4.4 Summary

In this chapter, the simulation outcomes and the proposed protocol's performance evaluation are discussed. For UWSN, an energy-efficient routing strategy has been proposed. The key objective of the proposed scheme is to deal with the problems of comparable schemes affecting packet delivery ratio, end-to-end delay, energy efficiency, or network longevity. A standard network simulator, called NS-2, is used for simulation and experimentation in order to study protocol performance. While taking performance indicators into consideration, a comparison analysis of the proposed plan with relevant schemes has also been carried out. It is proved from the findings that the proposed AEER performed better over the terms for all performance metrics.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Overview

The conclusion and future work of research are discussed in this chapter. The main objective of this research project was to determine the issues with existing routing schemes related to the addressing scheme, energy lifetime, packet delivery ratio, and delay and to provide solutions. The NS-2 simulator is used to evaluate how effectively the proposed energy-efficient routing protocol performs. Performance measures are employed to contrast the outcomes with previous schemes. The purpose of the proposed Protocol is to improve the prior Hop by Hop Dynamic Addressing Based Scheme (H2-DAB) with fresh methods and techniques. The important contributions of this research are explained in Section 5.2 of this chapter, which provides a more concise description of the research. Section 5.3 discusses a few problems and possible approaches to improving the research. Its primary objective of this thesis is to create an energy-efficient routing protocol by employing underwater nodes with an improved addressing scheme and an enhanced energy lifetime. Furthermore, a comparison with current state-of-the-art methodologies is done to evaluate the impact of the proposed model.

5.2 Summary of contribution

Underwater Wireless Sensor Networks (UWSNs) rely on energy-efficient routing protocols to optimize communication and data transfer while reducing energy consumption. The following is a list of their contributions to UWSNs:

i. **Energy conservation:** As sensor nodes are frequently powered by finite and non-rechargeable batteries in UWSNs, energy-efficient routing methods seek to reduce energy usage in these networks. These protocols enhance data routing to cut down on wasteful energy use while transmitting data.

ii. **Enhanced Network Lifetime:** By saving energy, these protocols help to extend the operational lifetime of UWSNs. . This is crucial for long-term underwater monitoring and data collecting jobs, like monitoring underwater exploration, and environmental monitoring.

iii. **Dynamic Routing:** In UWSNs, a lot of energy-efficient routing protocols use adaptive routing techniques. Based on the current network parameters, including node energy levels, link quality, and data traffic patterns, they dynamically choose the optimum path for data transmission.

iv. **Data Aggregation:** Prior to sending data to the sink node, several protocols encourage data aggregation at intermediate nodes. This lowers the amount of transmissions and, as a result, the network's energy usage. Sleep-wake scheduling methods are frequently used in energy-efficient routing protocols, enabling nodes to go into low-power sleep states when not actively involved in data forwarding or sensing. By doing this, idle energy use is reduced.

v. **Reliability:** By choosing paths with minimal interference and increasing the chance of successful data transmission, these protocols also put a strong emphasis on assuring consistent information delivery. To increase reliability, they might use tactics for retransmission and error correction. Depending on the needs of the application, certain energy-efficient routing algorithms prioritize QoS characteristics like delay or packet loss. They customize routing choices to satisfy the unique requirements of the deployed UWSN.

vi. **Distributed and Centralized Approaches:** Depending on the size and complexity of the network, energy-efficient routing protocols may use either distributed or centralized control mechanisms. For scalability, distributed protocols are frequently used whereas centralized methods can provide superior optimization in smaller networks.

vii. **Security:** To safeguard data transmissions from dangers like eavesdropping, manipulation, or node compromise—which are crucial in sensitive undersea applications—some energy-efficient routing protocols also include security features.

In summary, UWSNs require energy-efficient routing techniques to optimize energy use, increase network lifetime, and guarantee reliable data transmission. Through a variety of strategies, including as adaptive routing, data aggregation, sleep-wake scheduling, and considerations for QoS and security, they succeed in achieving these objectives and ultimately increase the efficiency of underwater sensor networks.

5.3 Applications

In Underwater Wireless Sensor Networks (UWSNs), energy-efficient routing algorithms find a wide range of applications across multiple disciplines because of their capacity to decrease energy consumption and extend network lifetime. Here are a few key applications.

i. **Environmental Monitoring:** Oceanic and aquatic ecosystems are frequently observed using UWSNs. Sensor nodes can collect information on water temperature, salinity, pollution levels, and marine life activity for a long time because to energy-efficient routing.

ii. **Underwater Exploration:** Energy-efficient routing is essential for missions involving underwater investigation, such as those involving the finding of natural resources or underwater archaeology. It enables effective communication between sensors and autonomous underwater vehicles (AUVs) while preserving energy for extended missions.

iii. **Oil and Gas industry:** UWSNs are used in the oil and gas industry to keep an eye on undersea oil and gas pipelines. Routing that uses less energy transmits information regarding pipeline pressure, temperature, and integrity, which lowers maintenance costs and environmental dangers.

iv. **Aquaculture:** UWSNs may track the health of aquatic animals, oxygen levels in the water, and water quality in aquaculture facilities. Sensor nodes can run for longer periods of time because to energy-efficient routing, which lowers maintenance requirements.

v. **Disaster Management:** UWSNs can be used in disaster management, particularly in situations like tsunami detection or underwater earthquake monitoring. Routing that conserves energy guarantees the timely transmission of vital information.

vi. **Networks for Underwater Communications:** In undersea communication networks, where dependable data interchange is crucial for a variety of applications, including offshore drilling operations and offshore renewable energy farms, energy-efficient routing plays a crucial role.

vii. **Diving for rescue and search purposes:** UWSNs can help with search and rescue operations by finding submerged objects or people who are in trouble. Coordination of AUVs and sensor nodes for effective data collection and communication is made possible by energy-efficient routing.

Energy-efficient routing protocols play an essential role in all of these applications for maximizing UWSN performance and reliability and assuring the effective use of scarce energy resources, eventually improving the success and sustainability of underwater operations.

5.4 Future Work

As the future direction, by updating the protocol and deploying more nodes, we hope to improve the protocol's performance and packet delivery ratio. It is possible to incorporate overhead in terms of control messages, packet processing, and decision-making when using several nodes and energy-efficient routing, although doing so could lower the efficiency advantages overall. Therefore, although proposing a plan to deal with these problems, the proposal can be improved further by adding several node sinks. There are a number of curious possibilities for further study and development in the area of underwater sensor networks (UWSNs), which is a sector that is constantly changing. The following are some prospective future research fields for underwater sensor networks:

i. **Energy-Efficient Protocols:** Increasing the lifespan of the network and reducing energy consumption need the development of more energy-efficient routing and communication protocols. Future studies could concentrate on streamlining power management procedures and lowering communication overhead.

ii. **Improved Underwater Localization:** To increase the precision of node positioning in UWSNs, it is essential to improve underwater localization algorithms. Future research could focus on the creation of original localization algorithms that take use of improvements in magnetic- and acoustic-based localization techniques.

iii. **Adaptive and Cognitive Networks:** Networks can dynamically alter their behavior in response to shifting environmental conditions, network requirements, and resource availability. This might result in networks that are more resilient and self-improving. Using cutting-edge information processing and data fusion methods to effectively handle and analyze data gathered from sensors in real-time. For applications like environmental monitoring, where quick data analysis is essential, this is significant. Creating strong security systems to defend UWSNs against dangers including eavesdropping, jamming, and intrusion. Security will become more of an issue when UWSNs are implemented into crucial applications.

iv. **Reliable Underwater Communication:** Developing error-tolerant communication methods is necessary for dependable data transmission in noisy and difficult underwater environments. Possible areas for development include interference reduction, adaptive modulation, and forward error correction. Combining UWSNs and autonomous underwater vehicles (AUVs) to collect data and maintain networks more effectively. Cognitive AUVs could carry out sophisticated activities and adjust to shifting network conditions.

Future objectives consist of adding more sinks to the protocol in order to improve its performance and packet delivery ratio even more. Multiple sink deployment requires maintenance and updating due to shifting sink positions, which could also result in higher communication overhead. Adding more sinks and an approach to deal with these shortcomings will therefore improve the proposed protocol significantly.

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