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ASurvey on UWSN: Energy Efficiency and Routing Protocol

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Abstract- Underwater Wireless Sensor Networks (UWSNs) are networks of underwater sensors that communicate wirelessly to collect and disseminate data. These networks are typically deployed in aquatic environments, such as oceans, lakes, and rivers, to monitor various physical, chemical, and biological parameters. UWSNs are used for a wide range of applications, such as environmental monitoring, oceanography, underwater exploration, and military surveillance. The sensors in these networks can measure various parameters, such as temperature, pressure, salinity, sound, and light, and transmit the data wirelessly to a central location for analysis and interpretation. UWSNs face several challenges, such as limited bandwidth, long propagation delays, high bit error rates, and high energy consumption, due to the harsh underwater environment. These challenges make it difficult to achieve efficient and reliable data transmission in UWSNs. To address these challenges, various routing protocols, such as Depth-based Routing, Delay Sensitive Routing, and Hydrocast, have been proposed and developed for UWSNs. These protocols aim to provide efficient and reliable data transmission in the challenging underwater environment. In this paper, we conduct a comprehensive literature review on existing research in the field of energy efficient underwater communication and routing protocols. We start with the detailed overview of architecture of UWSN and transmission of data and the challenges in underwater wireless communication. Next, we discuss the performance metrics to increase the UWSN's energy efficiency and the lifetime. Then, we review different routing algorithms suggested by several researchers for underwater wireless communication for energy optimization. We conclude with the detailed discussion of alternative routing algorithms that can overcome the existing limitations and provide efficient, scalable, and robust communication in UWSNs.

Keywords- Underwater Wireless Sensor Networks, Architecture, Routing, Energy efficiency

I. INTRODUCTION

From the sunlit open waters of the shore to the lightless depths and from the warm tropics to icy Antarctic the arena's oceans cowl 70% of the earth's surface and form the earth's habitat. Earth's surface is protected with the aid of seventy one% of water. Oceans hold approximately 96.5 percent of all earth's water. Water also exists in rivers, lakes and so forth. Water includes about 80% of all existence in the world.

In underwater, lot of things including pollutants, ordinary fishing, devastation of essential habitats and many others are setting marine lifestyles beneath huge stress. To eradicate these factors underwater wireless sensor network technology gave birth. Underwater wireless sensor networks (UWSN) is a wireless network deployed in underwater surroundings using some forms of physical sensors with acoustic functionality to carry out collaborative monitoring and data processing obligations. These sensor nodes may be used for underwater facts collection, pollutants monitoring, offshore exploration, weather recording, prediction of natural screw ups, search and survey missions and observe of marine existence.

Influenced by way of the earlier studies on underwater wireless sensor network, the goal of this paper is to check some trendy principles concerning minimizing the energy consumption of network. In the scenario, we should examine the network in all components such as routing, clustering, mac protocols and its role, scheduling and some query processing. Hence, this survey paper reviews the researchers' techniques to enhance energy and lifetime of the network.

II. ANALYSIS OF UNDERWATER WIRELESS COMMUNICATION

In this section we give attention to the communication beneath water in terms of structure and the challenges faced inside the communication.

1. Architecture of UWSN

The sensors are the nodes with acoustic modems, and are disbursed in either shallow or deep water. Every sensor node can sense (special sensors can sense distinct environmental data, consisting of the water quality, pressure, temperature, metallic, and chemical and biological factors), relay, and forward statistics. The statistics should be transferred to the floor of the water, known as sink(s).

Sinks are the nodes with each acoustic and radio modems. Sinks can be buoys, ships, or Autonomous Surface Vehicles. When the data arrives at sinks(through acoustic channels), the sinks will forward records to the remote monitoring center (thru radio channels). The monitoring center is frequently on the seaside, and is answerable for tracking the water areas. The monitoring center collects, analyzes, and deals with the records from the water areas.

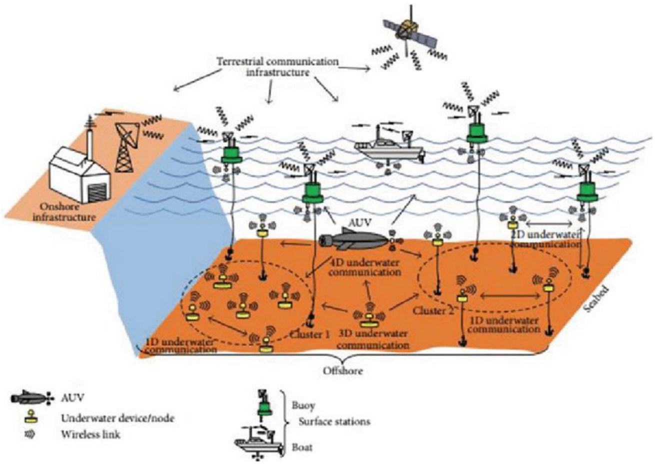

Figure 1 Architecture of UWSN

1. 1D-UWSN Architecture:

According to [1], UWSN architecture refers to a network wherein the sensor nodes are deployed autonomously. Every sensor node is a stand-alone network itself, which senses, process and transmits the facts to remote station. A node in this sort of structure can be a floating buoy which can be deployed under water for a particular time period to experience records after which drift toward the surface to transmit the sensed information to the remote station. It is able to be anautonomousunderwater vehicle(AUV) which dives inside the water, sense or accumulate the underwater residences, and relay the facts to the remote station. In 1D-UWSN the nodes uses acoustic, radio frequency (rf), or optical communication to communicate. Moreover, the topological nature of 1D-UWSN is star where the transmission throughout the sensor node and the far flung station is carried over a single hop.

2. 2D-WSN Architecture:

This architecture refers to a network in which a group of sensor nodes (cluster) are deployed underwater. Every cluster has a cluster head (also known as anchor node). Participants of the cluster acquire the data and send it to the anchor node. The anchor node relays it to the surface buoyant nodes. It communicates using two dimensions i) each member of the cluster communicates with its anchor node with horizontal link. ii) The anchor node communicates with the floor buoyant node with vertical link. Communication between Nodes is done using acoustic, optical or Radio Frequency. For the cluster of nodes, the network association can be star, mesh or ring. This structure is used for time-critical or postpone tolerant applications.

3. 3D-WSN Architecture:

In this architecture the sensors are deployed within the shape of clusters and are anchored at exclusive depths. There are 3 communication situations. They're i) intercluster communication of nodes at specific depths. ii) intracluster (sensor-anchor) communication. iii) anchor –buoyant node communication. In all communication eventualities, acoustic, RF and optical links may be used.

4. 4D-WSN Architecture:

It's miles designed via the mixture of fixed UWSN (i.e) Three-D-UWSN and mobile UWSNs. The mobile UWSN includes remotely operative underwater vehicle(ROVs) to accumulate records from the anchor nodes and relay the statistics to the remote station. ROV may be self-reliant submersible robots, Vehicles, ships and submarines.

2. Challenges in Underwater Wireless Communication

The most important issues in underwater networks are as follows [9]:

1. Power- Acoustic communication consumes extra power compared to RF terrestrial links. Moreover, recharging or changing batteries is costly and time eating. Batteries in nodes cannot be without problems recharged or changed regularly because of harsh underwater conditions and the expense of these operations. Therefore design considerations of underwater networks must bear in mind the energy intake of underwater nodes to increase community lifetime to at the least as long as the undertaking period.

2. Propagation delay: Underwater RF propagation delay is at the least five times greater than that in OTA medium. Due to intense attenuation, RF is nearly by no means used for UWC. The dominant PHY layer generation currently used underwater is acoustics. But, the gradual propagation speed of sound underwater introduces large propagation delay in information communication, ensuing in multipath; inter symbol interference (ISI), and doppler troubles.

3. Channel impairments-The underwater channel is fairly dynamic due to water turbulence and node mobility. Moreover, underwater items such as marine life, plantations, and lines can result in multipath and fading issues for UOC. Moreover UOC demands unobstructed, best alignment of the transmitter-receiver pair in order that data may be transmitted using light. Consequently, various water cur-rents and waves can easily impair optical links and cause signal degradation.

4. Bit Error Rate (BER)- UWC suffers from high BER because of the enormously dynamic surroundings ensuing in temporary losses in connectivity among CNs. High BER calls for clever receiver layout with adaptive blunders correction capabilities that could yield robust UWCNs towards excessive channel uncertainties.

5. Transmission media- The communication under the sea is based totally on acoustic communications as opposed to radio communications. Exceptional protocols are required for establishing the conversation gadget below the ocean water.

6. Propagation speed- The propagation speed of gadgets in underwater networks is about 200,000 times slower than in land network. As an example the propagation velocity of radio channel 300,000,000 m/s in land while in acoustic channels it's miles best around 1500 m/s. So addressing the delay in packet transmission can be a first-rate problem.

7. Transmission range- The transmission range of underwater sensor network may be approximately ten instances longer than within terrestrial network. The indicators may be absorbed via the water within the acoustic environment. So the indicators have to be transmitted in low frequency. Lower frequency shows longer transmission range; which in flip effects in excessive dangers for interferences and collisions for the duration of the transmission of information. Hence, avoidance of interferences and collisions is considered as any other assignment in underwater communication.

8. Transmission Rate: The acoustic surroundings are going for slender bandwidth, which lowers the transmission rate (approximately 10 kbps). Hence, efficient usage of bandwidth may be very essential task to be addressed in underwater communication.

9. Limited Storage Capacity- Conventional devices have constrained underwater duration because of loss of statistics garage area and for that reason ought to be physically retrieved to recover the records.

10. Low bandwidth- The available bandwidth in underwater acoustic communications is critically confined i.e. in the range of (30 to 3000 Hz)

11. High Bit Error Rate (BER)- The underwater channel is significantly impaired due to multi-direction and fading which leads to an excessive BER or even transient losses of connectivity (shadow zones).

12. Safety [37]-Data transmission within UAC networks can be effortlessly eavesdropped, while UOC networks can be without difficulty detected visually. Moreover, the energy limited nature of UWCNs and harsh channel characteristics pose intense regulations on deploying canonical energy-hungry cryptographic techniques, consisting of encryption, in these networks. For the reason that army is one among the most important stakeholders in this area, securing communication channels for transmission of challenge-critical facts is a primary problem that wishes to be addressed. UMIC is a promising PHY layer era in this issue because it's far extra difficult to intercept electromagnetic waves in comparison to sound and optics.

III. TRANSMISSION OF DATA IN UWSN ENVIRONMENT

In UWSN transmission, according to author [2] there are 3 routing techniques generally used.

At the first direct transmission approach, each sensor node at once sends a datagram directly to the sink. This can consequence within the decrease of nodes positioned a great distance from the sink endpoint.

Its 2nd transmission approach is based on a hop-via-hop transmission. Each entity detects facts and transfers it to the sink by deciding on the closest neighbour as a routing route.[4]. In the end, the endpoints' amount will increase closer to the sink nodes. Because of this easy reality, nodes forestall developing sooner at the beginning levels. For that reason further, the performance and lifelong of a network generally tend to decrease.

The 3rd routing protocol, broadly recognized as ''clustering-based routing,'' is one of the maximum fascinating to investigators. Each underwater detecting node can ship its accumulated facts to its correlating cluster heads (CHs). They then ship their collected information to the remote station. Accurate and complete transmission between nodes is decreased, bandwidth utilization is reduced, and the network's overall performance is more advantageous in this way.[5]. UWSNs have numerous one-of-a-kind capabilities, this is, long end-to-end delay, restrained bandwidth, and high bit error rate.[6]

Another routing protocol[2]-A depth controlled and energy efficient routing technique, that's primarily based on depth data, reduces time delay and energy utilization. On this technique, when an information sender sends the information to any other node with a decrease depth value than the sender and has overlapping lower intensity associates, the statistics could be transmitted to the minor depth node. Some other famous method is Genetic Algorithm (GA)[7].

It also hunts for maximum solutions by using imitating the perfectly natural evolutionary alternate, can deal with the optimization problems, and is efficient in figuring out the best multihop route between source and destination.A random framework is typically used to initialize the GA population. A fitness function analyzes the best members and picks them for in addition manufacturing. The population can improve, and the pleasant solution is observed repeatedly, performing choice, mutation, and crossover tactics. [8] As according to [9], the best mission within the massive-scale variation of UWCs is energy. UWSN's energy routing examines in most cases makes a specialty of efficient energy utilization.

IV. PERFORMANCE METRICS

The general overall performance of UWSN ought to be evaluated the usage of precise metrics. Right here we have the distinctive metrics to improve the UWSN's energy efficiency and life time[11].

1. Electricity consumption- According to [43] Energy consumption is the overall energy utilized for data transmission and data gathering by the network. It's far the difference between the initial electricity earlier than transmission and the electricity after transmission.

Energy consumption=Initial energy-Final energy

2. End to End delay-The End to End delay is also called as one-way delay(OWD) which refers to the time taken for a packet to be transmitted pass a network from source to destination. Additionally it is all delays caused by buffering for the duration of routing discovery latency, queuing at the interface queue, and retransmission delays at the MAC, propagation and switch times of facts packets

$$\text{End to End delay} = \frac{\sum(\text{stop time} - \text{start time})}{\text{Total number of packets}}$$

3. Packet Delivery ratio-According to [44], [45] A packet delivery ratio (PDR) is calculated as the overall packets transmitted to the total packets received from a source and destination to a goal tool at the network. Packet transport computes the success of transport when lack of packet is taken into account and the network performance is decided by way of packet delivery ratio, it's miles described as ratio among packets arrived and number of packet despatched with a multiplication velocity. The Packet Delivery Ratio is completely based on the obtained and generated packets as recorded inside the trace document. It's also described because the ratio among received packets via the destination and the generated packets through the source.

Packet Delivery Ratio = (Number of packets acquired / despatched) * Speed

4. Packet drop ratio-Packet loss can arise each time one or maybe greater sent packets fail to reach their destination[46]. Assume a node inside the network joins the UWSN, it'll not take part in the transmission manner until it gets authorization. It's far defined as the quantity of packets dropped to the wide variety of packets despatched

$$Pl=(Pdrop/Ps)x100$$

Wherein Pl is the packet loss, $Pdrop$ is the number of packets dropped, and Ps is the number of packets sent.

5. Communication Overhead- The sum of packets from one sensor node to the alternative is given as the range of packets being transmitted according to [12]. The overhead contact may contain the head of the routing table, the routing system and the packet shape in the sensor nodes

$$Co=(Pl/Pr)x100$$

whereCo is the conversation overhead, Pl is the number of packets lost and Pr is the number of packets obtained on the destination.

6. Throughput-It's miles the number of transmitted packets according to unit time. That is the ratio of total number of packets to the number of packets that have been despatched. The efficiency is in bits per second(bps) or in packets per second (pps) is calculated

$$\mu=Ps/P$$

In which µ is the throughput in s, Ps is the number of packets despatched, and p is the total number of packets.

7. Misbehaviour ratio: It's miles described as the number of packets stricken by wormhole assaults to the entire quantity of packets despatched

$$Pm=Pa/Ps$$

Wherein Pm is the misbehavior ratio, Pa is the range of packets attacked, and Ps is the number of packets despatched.

8. Connectivity ratio-It's miles defined as the ratio of susceptible connections to overall network connections $Cc=Cw/Cn$,

Where Cc is the connectivity ratio, Cw is the number of vulnerable connections, and Cn is the whole range of connections inside the network.

9. The life of the community-A performance measurement parameter in UWSNs is network lifetime, measured because the time it takes for the primary sensor's power to expire.[47]. The frequency of lively nodes, connections, and distribution affects the networks average lifespan. A performance dimension parameter in UWSNs is network lifetime, measured because the time for the primary sensor's strength to run out.

10. Network transmission loss results

The strength at one degree in a UWSN transmission network is as compared to the power at some other region and the connection.[16],[49–50]. The lesser consequences for community transmission loss display higher overall performance.

V. ROUTING PROTOCOLS

UWDSN consist of sensors and vehicles to collect the data and interacts between them to perform collaborative tasks. Many terrestrial wireless sensors methodologies and procedures cannot be applied to the underwater communication. Radio signals, which is frequently used in terrestrial communication travel long distances at low frequencies, with massive antennas and considerable network throughput but reduces the UWSN's entire network life span. Furthermore, auditory transmission delays more than the radio transmission. Hence Acoustics transmissions are generally used which supports long communication ranges up to kilometres with a high data rate performance and high latency with low propagation speed. Several researchers have suggested different routing algorithms for underwater wireless communication for energy optimization. A few are as follows:

1. Cluster based Routing

An underwater wireless sensor network contains vast number of sensors to observe the underwater environment. However, these sensors are restricted to energy, resulting energy efficiency being a major challenge. Routing based on clustering is considered as the energy efficiency solutions for UWSN.

Nguyen et al. [11] developed a low –energy adaptive clustering hierarchy(LEACH), cluster-based routing protocol for UWSN. It was developed to address the challenges of energy efficiency, scalability, and load balancing in UWSNs.In LEACH, nodes form clusters and elect a cluster head, which is responsible for aggregating data from the other nodes in the cluster and forwarding it to the sink node. The cluster head selection is done based on a probabilistic approach, which balances energy consumption among the nodes. LEACH is a promising routing protocol for UWSNs, but it may require modifications and optimizations to address the specific challenges of the underwater communication environment.

Gola and Gupta[18] proposed a routing solution that aims to improve energy efficiency and void avoidance in UASNs by using a grey wolf optimization algorithm. The algorithm is designed to optimize the routing path based on energy consumption, void avoidance, and communication reliability. Bhattacharjya et al[13] introduced an energy-efficient design in which energy costs are reduced and efficiency is increased in the underwater scenario. It uses the benefits of cluster head and multi-hop transmission. This cluster based underwater wireless sensor networks(CUWSN) increases the network lifetime by using multi-hop transmission.

2.Localization based Routing:

Localization-based routing is a routing method in Underwater Wireless Sensor Networks (UWSNs) that uses node localization information to optimize the routing decision. In this method, the position of the nodes is estimated using techniques such as range-based or angle-based localization, and the routing decision is made based on the node position information. Goyal N, Dave M, and VermaAK[15] discusses the various data aggregation approaches, including energy-efficient data aggregation, load-balanced data aggregation, and efficient data collection methods. A new routing method Vector-based Forwarding is introduced. The main advantage of vector-based forwarding is that it can provide efficient and scalable routing in UWSNs by reducing the number of control messages and minimizing the processing overhead. By using the vector representation of node positions, the routing algorithm can make the forwarding decision based on the topological information, which can improve network performance, reduce energy consumption, and enhance network robustness. However, the accuracy of node localization is a crucial factor in the success of vector-based forwarding, and it is often challenging to achieve high accuracy in the underwater environment due to the complex underwater acoustic channel and limited sensing capabilities of underwater nodes. The proposed routing strategy of Albukhary and Bouabdallah[19],a depth-controlled route (DCR) aims to balance the energy consumption and data transmission delay of the nodes in the network by dynamically adjusting the routing path based on the current network conditions

3. Localization-free Routing:

The nodes in the network do not require prior knowledge of their positions for data transmission. Instead, the routing decisions are based on other parameters such as the node's depth, residual energy, or received signal strength. The goal of localization-free routing is to reduce the cost and complexity of deploying UWSN by eliminating the need for localization algorithms. Zhu andWei [17] presents a new energy efficient routing protocol for Underwater Wireless Sensor Networks (UWSN). The proposed protocol is based on dividing the network into multiple layers and unequal clusters, which helps to balance the energy consumption and data transmission delay.

4. Depth-based Routing:

A Conventional localization-free routing method named Depth Controlled Routing refers to a routing protocol where the routing decision is based on the depth information of the nodes in the network. This information is used to determine the best route for data transmission. Umesh Kumar Lilhore et al [2] proposed a protocol which takes into account the depth information of the nodes to determine the best route for data transmission, which helps improve the reliability and efficiency of data transmission in underwater environments where signal attenuation and transmission delay are major challenges. The protocol is designed to conserve energy by reducing the number of control messages and selecting routes that have less energy consumption. This method uses a balance routing protocol (BRP), Aggregation ring protocol (ARP) and Genetic Algorithm(GA) which concentrates in reducing the energy consumption in UWSNs.

Table -1 Comparison of Routing Schemes

Routing Scheme/ Protocol	Type of Protocol	Benefit	Limitation	Ref
Depth-based routing	Location-free routing protocol	Increase the packet delivery ratio	In a sparse network, it performs poor	[41]
lay-Sensitive DBR	Multi-path routing protocol	Reduced Latency	Scalability	[31]
AUV-Aided Efficiency Data Gathering	Multicast routing protocol	Reduced Energy consumption	High cost	[32]
Energy Efficient Reliable Data Transmission	Multicast routing protocol	Reduced Throughput	Complexity	[33]
Stratification-based data collection	Hierarchical routing protocol	Reduced overhead	complexity	[34]
Energy efficient multiobjective evolutionary routing	Multiobjective optimization based protocol	Increased Network lifetime	Scalability	[36]
Distributed Sensor Web Routing	Location-free routing protocol	Provides better throughput	Consumes more power	[38]
Quality-of-Service Routing protocol	Location-free routing protocol	Higher packet delivery ratio	Consumes more power	[39]
Hydro-cast routing protocol	Location-free routing protocol	Consume less energy	Poor performance in sparse network	[40]

VI. CONCLUSION

Energy efficiency and routing are important challenges in Underwater Wireless Sensor Networks (UWSNs). Energy efficiency aims to reduce energy consumption while maintaining network performance. Routing involves finding the optimal path for data transmission.

To improve energy efficiency in UWSNs, techniques such as duty-cycling, sleep-wake scheduling, and power management can be used. In duty-cycling, nodes are turned on and off at specific intervals to conserve energy. Sleep-wake scheduling allows nodes to enter a low-power sleep state when not transmitting or receiving data. Power management involves controlling the power consumption of individual components, such as radio transceivers, to minimize energy usage.

For routing in UWSNs, algorithms such as Directed Diffusion, Position-based Routing, and Maximum lifetime routing can be used. Directed Diffusion routes data from the source node to the sink node through intermediate nodes that match certain criteria. Position-based Routing uses the node's position information to find the shortest path. Maximum lifetime routing aims to extend the network lifetime by selecting routes that minimize energy consumption.

In conclusion, energy efficiency and routing are important challenges in UWSNs and various techniques and algorithms exist to address these challenges.The goal of this paper is to develop routing algorithms that can overcome the existing limitations and provide efficient, scalable, and robust communication in UWSNs.

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