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A Literature Survey for Underwater Wireless Sensor Networks

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Abstract: There are several underwater applications for underwater wireless sensor networks (UWSN), including ocean monitoring, seismic monitoring, environmental monitoring, and bottom exploration. UWSNs are constrained by a number of issues, including high ocean interference and noise, high propagation delay, limited bandwidth, changing network topology, and low sensor node battery energy. One way to deal with these problems is to build routing protocols. Data can be efficiently transferred across a network from the source node to the destination node using a routing protocol. Review of underwater routing protocols for UWSNs is presented in this paper. We divide the present underwater routing protocols into three groups: protocols based on energy, data, and geographic information. In this article, we include the recently proposed underwater routing protocols.

Keywords: Energy-based protocol, Underwater Wireless Sensor Network, Routing Protocol, Data-Based Protocol.

1. Introduction:

Underwater wireless sensor networks (UWSNs) consist of a variable number of sensor node and autonomous vehicles that are deployed to perform collaborative task for various applications. To achieve this objective, sensors and autonomous vehicles are placed in an autonomous network which can acquire to the characteristics of the ocean environment [1].

Wireless communication in underwater is one of the enabling technologies for the development of future ocean-observation systems and monitoring. Applications of underwater sensing range from military purposes to pollution monitoring and include environment monitoring, pollution control, climate status and prediction of natural disasters. It improves the search and survey missions, and study of marine life.

Routing in underwater wireless sensor networks plays important role due to the difference between the characteristics of the acoustic communication to that of the radio-magnetic waves. Various protocols have been designed to satisfy the different requirements of the acoustic communications such as delay efficiency, bandwidth efficiency, reliability, cost efficiency, delivery ratio. But the major requirement that has been highlighted is energy efficiency. Energy efficiency depends on many metrics which should be considered while designing the protocol. We focus basically at helping the protocol designers in providing an overview of the existing protocols and propose an optimized routing scheme to improve performance. Nowadays, people have proposed and developed some routing protocols. Underwater wireless sensor networks can be divided into deep water and shallow water. Underwater wireless sensor networks routing protocols further can be classified based on communication as acoustic communication, radio wave communication and optical communication. In underwater acoustic sensor networks, there are number of corresponding protocols, for example, VBF [2], MURAO [3], DDD algorithm [4], Void-Aware Pressure Routing [5], GPS-free Routing Protocol [6] and DBMR [7].

Radio-frequency waves can be transmitted well on land. However, radio waves are attenuated severely in seawater [3]. The ultra-low frequency electromagnetic waves of 30 to 300 Hz can penetrate more than 100 meters of seawater. However, it requires a long receiving antenna that cannot be realized with a small sensor node. Therefore, radio waves can only achieve high-speed communication at short distances [4]. Due to the large available bandwidth, optical communication can provide high data rates (where Gbps can be achieved) within a few tens of meters [5]. The BlueComm and Ambalux underwater optical wireless communication (UOWC) system can provide data transmission with a range of about 100 meters. The study shows that it is possible to achieve LED-based visible light communication over a link distance of 500m in pure water [2]. Underwater optical communication has a strong information-carrying capacity and can form a large-capacity wireless communication link. However, the communication quality of UOWC is closely related to the clarity of water and the light signal is severely absorbed and scattered.

2. Related Work:

In the wireless sensor network, the route is a significant problem, and numerous routing techniques have been developed to address it. We will introduce some related studies about the underwater routing protocols in this section. We will provide the fundamental designs of underwater sensor networks in the interim. The most important component in determining the network's energy usage and scalability is its topology. An active area of research is the wireless sensor network topology. Three major sensor network topologies are used in the current research: a two-dimensional static underwater sensor network, a three-dimensional static underwater sensor network, and a three-dimensional underwater sensor network with autonomous underwater vehicles [4]. (AUVs).

the structure of the two-dimensional static underwater sensor network. The sensor nodes in the two-dimensional static networks are fixed in the seabed region, and they are in charge of gathering data and relaying it via a single or multiple hops to the relay station placed on the water's surface. As a result, the two-dimensional sensor networks place heavy demands on the sensor nodes' communication skills. A direct link connection is the simplest approach to reach sensor nodes in a two-dimensional underwater sensor network. But it might not be the most energy-efficient alternative because of the long-distance data transmission. Furthermore, due to increased noise interference brought on by high transmission power, direct links are likely to impair network throughput. As a result, multihop pathways are used in networks to carry data information, reducing the energy needed to build underwater paths [11]. The most common applications of two-dimensional underwater sensor networks are for geological monitoring and underwater environmental monitoring [12]. the network's three-dimensional structure. A more thorough gathering of underwater data information is offered by three-dimensional underwater sensor networks [13]. Only data about a specific bottom region may be acquired from the two-dimensional underwater sensor network. The underwater depth of the sensor nodes in the three-dimensional underwater network can be changed to gather ocean information at various depths. The network structure of the three-dimensional underwater sensor networks with AUVs is similar to that of the static underwater sensor networks in three dimensions. AUVs that can move freely can replace the fixed sensor nodes in the three-dimensional underwater sensor network. An extension of the static network that can improve the underwater sensor network's communication performance is the three-dimensional underwater network with AUVs. The three-dimensional underwater sensor network's nodes, which are either sensors or AUVs, are randomly placed in the water. However, because of the unique characteristics of the underwater environment, three-dimensional underwater network structures are challenging to deploy and readily damaged. Typically, marine biochemical processes, environmental contamination, and marine military management use three-dimensional underwater sensor networks.

In recent years, there have been a few surveys on underwater routing systems. Localization-based and localization-free protocols are the two groups into which the routing protocols in [9] are split. These groups are further broken into subgroups based on the issues they address or the key factors they take into account when transmitting the information. Each protocol's advantages are emphasised. The author [8] categorises routing protocols into three groups based on protocol characteristics and routing algorithms: non-cross-layer design protocols, classic cross-layer design protocols, and clever algorithm based routing protocols. The majority of the sophisticated algorithms discussed in [8] can't be used in an underwater setting, though. Routing protocols are typically divided into three categories in [17]: proactive protocols, reactive protocols, and geographical protocols. Because sensor node movement makes it challenging to build a transmission line, proactive methods are not appropriate for UWSNs. In the underwater networks, reactive protocols will have a large delay. As a result, paper [17] examines routing strategies based on location data. Senderside-based protocols and receiver-side-based protocols are the two categories into which the existing underwater routing protocols based on a route decision-maker are separated in [14]. Researchers may use this summary to build routes based on node properties. The aforementioned methods, though, are appropriate for static UWSNs. Only four typical underwater routing protocols are introduced by the authors in [20], who then analyse these routing protocols using numerical simulation. We summarise and delineate the benefits of routing protocol survey papers from recent years for a better understanding.

Designing routing protocols still presents numerous difficulties as compared to underwater routing protocols that already exist.

Underwater sensor nodes move as a result of sustained water flow, which will seriously affect Doppler effects [23]. Meanwhile, it is highly challenging to install underwater sensor nodes and the sensors cannot be changed due to the unique characteristics of the underwater environment. Data transmission effectiveness and sensor quality are given more consideration [11]. Diverse degrees of attenuation and significant noise are present in the undersea environment for the signals. The channel's drawbacks include a limited bandwidth, a lengthy transmission latency, instability, and significant energy usage. As a result, it is imperative to create an efficient routing system for underwater sensor networks.

This page suggests a thorough comparison of the underwater routing methods. This page provides the most recent publications and extensive citations as compared to other routing protocols survey papers. We classify these routing protocols into three groups depending on their characteristics: energy-based protocols, database-based protocols, and geographic information-based protocols. These three different kinds of routing protocols are further broken down into a number of subcategories based on the primary factors taken into account throughout the routing process. The division includes groups depending on the sensor nodes' precise geographic information, data transmission mechanism, and energy consumption. In this article, the UWSNs routing protocols' precise classifications are provided. Understanding the technology of researching undersea resources and marine defence can be improved with a thorough introduction of the pertinent understanding of underwater routing protocols. The routing protocols are summarised in this article in a unique way based on the data forwarding mechanism. To make it easier for the reader to locate the necessary protocol information, we present the various underwater routing protocols' taxonomy systems.

PER [24]: There are several ways in which underwater sensor networks differ greatly from conventional land-based wireless sensor networks, including limited bandwidth and significant propagation latency, floating node mobility, power efficiency, and more. For UWSNs, a power-efficient routing protocol (PER) is created to address these issues. A forwarding node selector is one of two modules that make up the proposed protocol. energy-based routing protocol categorization. includes a system for forwarding tree cutting. The forwarding node selection uses fuzzy logic to decide which sensors are appropriate to send the data to the destination node. The forwarding tree trimming method is used to cut back on the extra power that sensor nodes consume when transmitting data.

The undersea routing protocol's cross-stack architecture can enhance single-hop performance, according to WALL [25]. A routing method for wireless acoustic line links (WALLs) is suggested that makes use of the recognised set of links for unicast routing. The suggested routing protocol maximises network lifetime while ensuring network QoS. By taking into account underwater channel circumstances, the authors advocate a novel cross-stack model for collaboratively building the physical and data-link layers that provide a set of links. The cross-stack model will be used by each node, giving the network layer a way to gauge the throughput of a communication link. In order to develop energy-efficient routing with the shortest end-to-end packet delay, the network layer will make use of throughput and energy consumption data.

MARL [26]: For underwater optical sensor networks, a novel routing protocol based on multi-agent reinforcement learning (MARL) is suggested (UOWSN). The protocol aims to maximise network lifetime and enable dynamic route selection by information interacting between adjacent nodes. To address the issues of link fragility and energy-hungry in UOWSN, the authors incorporate the residual energy of nodes and link quality into the design of the reward and Q-value function of nodes. According to the highest Q-value, the route and protocol apply an intelligence mechanism to choose the nexthop node. However, several control message transfers could be to blame for the data transmission collision.

QL-EEBDG [27]: For underwater sensor networks, a Q-Learning based energy-efficient and balanced data collecting routing protocol (QL-EEBDG) is suggested. Based on the source node's residual energy and the neighbouring nodes' group energies, the forwarder node is calculated. In [28], the authors employ mixed data transmissions to optimise network lifetime while balancing energy usage using the EBDG protocol. However, during data transmissions, the forwarder node is continually chosen until it fails. In [27], the authors use the Q-learning machine learning technique to address the death problem (QL). As a result, the QL algorithm optimises node behaviour in terms of energy conservation and prevents the void hole in the protocol before it occurs. To balance the node's energy, the network could decide to delay data transmission.

RECRP [29]: A dependable energy-efficient cross-layer routing protocol is suggested due to the unique difficulties faced by UWSNs. For the purpose of ensuring the two-hop packet delivery rate and energy balance, the authors suggest a conservative optimal Max-Min model. The next-hop node is chosen while broadcast power and channel frequency are dynamically controlled using Doppler scale measurement and received signal strength indicator (RSSI). Updates to routing tables and forwarding phases are included in RECRP. The authors employ a technique to construct and update the routing table during the updating phase in order to handle the communication gap. The next hop is chosen during the forwarding stages using the Max-Min model. It is challenging to implement the algorithms in the actual environment because of the unique properties of the undersea.

A wholly opportunistic routing algorithm (TORA) is suggested for UWSNs in TORA [30]. To eliminate horizontal transmission, decrease end-to-end latency, address the issue of void nodes, and increase network throughput and energy efficiency, the TORA protocol is proposed. The proposed approach operates in three stages: data transmission, candidate forwarder selection, and node localisation. The multi-sink node-based proposed technique is implemented at the water's surface. Network nodes are located using the TOA (Time of Arrival) and range. The position coordinates and residual energy of the nodes are used to choose the optimum forwarding node that is closer to the destination. In order to transmit data to the sink node, numerous short and active links are combined.

EGBLOAD [31]: To distribute data traffic across network nodes and achieve efficient energy usage, the energy grade and balanced load distribution corona-based technique (EGBLOAD) is presented. To prevent heavy traffic on intermediate nodes, the forwarder node's transmission power is based on the distance, residual energy, and data traffic. Each forwarder node's energy grade is determined by its distance to the destination. The energy level is used to choose the forwarder node. The entire network's nodes will have low energy consumption efficiency if the forwarder node is chosen with a light traffic load.

HyDRO [32]: The harvesting-aware data routing (HyDRO) is a system that optimises the network-wide through the sharing of local information while taking into account the channel circumstances and the remaining energy within the routing range. Based on remaining energy and anticipated harvestable energy, the best forwarding node is chosen. The protocol is driven by a reinforcement learning architecture that enables nodes to learn from their current settings, including the energy that is currently accessible and projected to be present in their immediate area as well as their most recent successes in forwarding packets (a measure of link quality). In order to extend the lifespan of the network, HyDRO arranges packets so that the leftover energy on the entire route is maximised toward the sink.

LFEER [33]: For UWSNs, localization-free energy-efficient routing, or LFEER, is suggested. The suggested protocol offers a technique for reducing energy consumption during data packet forwarding. The criteria for choosing a destination are specified by the LFEER protocol and are determined by a function based on the maximum residual energy, hop count, and link error rate. However, the information can be forwarded to the destination by any node within the transmission range, which uses a lot of energy. To address the issue, the authors of [33] suggest using localization-free energy-efficient cooperative routing (Co-LFEER). The Co-LFEER protocol chooses a single relay node and destination to regulate energy consumption. The relay node is given the second-highest value of the function, while the destination is given the highest value.

EnOR [34]: A new, standard lightweight energy-aware opportunistic routing (EnOR) protocol is put forth, which promotes balanced energy use and increases the lifetime of UWSN networks. Candidate set selection and candidate transmission prioritising are the two primary EnOR processes. EnOR uses the remaining energy, link dependability, and data packet forwarding to evaluate the transmission priority of forwarding candidate nodes. EnOR employs timer-based coordination to order the transmissions of the candidates so that each can be given a time slot depending on their priority. To prevent the node from operating as a forwarder until its battery runs out, the forwarding priority of the node might change over time.

SPRVA [35]: For underwater acoustic networks, the shortest path routing protocol based on the vertical angle (SPRVA) is suggested. The protocol chooses the best next-hop in accordance with the main priority, just like the EnOR protocol. The backup priority is indicated by the connection quality, whereas the primary priority is determined by the residual energy and angle between the propagation direction and the depth direction. The alternate priorities are applied when the candidate nodes' main priorities are same. The top priority can aid in choosing the fastest route and balancing the network's energy usage.

EBLE [36]: To increase the network lifetime for UWSNs, the energy balanced and lifetime extended routing protocol (EBLE) is suggested. The candidate forwarding set selection phase and the data transmission phase are the two stages of the EBLE data transmission process. In the first stage, each node calculates and stores its cost value while updating the potential forwarding nodes by broadcasting its position and remaining energy level information. The sensor nodes primarily forward data packets and update residual energy levels during the data transmission phase. Based on the cost function and residual energy level data, the best pathways are then chosen. The EBLE protocol has the ability to balance network energy usage and increase network longevity.

SEECR [37]: Security breaches in the UWSN environment play a significant role that requires attention. The performance of the underwater network can be improved by using the authors' proposed secure energy-efficient and cooperative routing (SEECR) protocol. The SEECR protocol makes effective use of energy through cooperation to extend the lifetime of the network. Additionally, to increase the effectiveness of data transfer, the SEECR protocol now includes a security mechanism to thwart security threats. The study enables researchers to comprehend the effects of security attacks in the context of UWSNs and take security measures into account when developing underwater routing protocols.

2) Protocols for Cluster-Based Routing: According to the needs of the routing protocol, the cluster-based routing protocols segment the entire network into dynamic clusters. Each cluster set consists of a cluster head node and a number of intra-cluster member nodes, and each cluster is capable of processing the data in the cluster area in accordance with the appropriate criteria. The cluster leader is in charge of overseeing the neighbouring nodes. To cut down on both data transmission and energy use, the cluster head can send the base station the processed data. The energy consumption is relatively high since the cluster head nodes must coordinate the activities of the nodes inside the cluster region and are in charge of data fusion and forwarding. Therefore, to balance node energy consumption in the network and enhance network lifetime, cluster-based underwater routing protocols typically follow the method of selecting the cluster head node. To follow, a detailed description of these cluster-based routing protocols is provided.

LEACH [38]: A cluster-based protocol called Low-Energy Adaptive Clustering Hierarchy (LEACH) is presented, which evenly distributes the energy load among the network's sensors. The LEACH protocol merges data into the routing protocol to lessen the amount of information that must be transmitted to the base station and reduce energy dissipation in sensor networks. It uses localised coordination to achieve scalability and robustness for the network. Each sensor node could function as a cluster head node in the LEACH protocol. The number of cluster head nodes required in the network and the number of times each node has previously served as a cluster head node are the main factors in choosing the cluster head node.

MLCEE [39]: To address the issue of unbalanced load transmission and energy consumption on sensor nodes, the multi-layer cluster-based energyefficient (MLCEE) protocol is put forth for UWSNs. MLCEE consists of three stages: layering the entire network from top to bottom, clustering the sensor nodes at the same layer, and sending the data to the sink nodes. The network's first layer is left unclustered, and any nodes in this layer send data straight to the sink node. At the same time, the cluster head (CH) is chosen based on residual energy and Bayesian probability, and data is sent through CHs using the hop-by-hop method.

JCRP [40]: For a three-dimensional underwater acoustic sensor network, a joint clustering and routing protocol (JCRP) is suggested. Probabilistic and non-probabilistic clustering protocols can be distinguished. Deterministic criteria are used in non-probabilistic clustering protocols to guarantee the validity and robustness of the CHs selection. The Cluster-Head node is chosen by the proposed protocol using a non-probabilistic method based on the weighted cost of residual energy and network connectivity. The network is made up of clusters at various levels, from the ocean to the surface. Three phases make up the proposed algorithm: node categorization and neighbour finding, temporary cluster head (TCH), final cluster head (FCH) selection, and route creation.

To increase data transmission reliability for UWSN-based applications, a novel quality-of-service (QoS) aware evolutionary cluster-based routing protocol (QERP) is presented. As a relay node for information, the CH node with the lowest data traffic load and energy consumption is chosen. Relay nodes can alter their transmission power level in the interim to save energy. By taking into account the keeping history of the relay nodes in the node routing table, this approach can prevent the energy depletion of the same CH nodes being selected repeatedly in various directions. Data path loops, network latency, and energy consumption are decreased using a QoS-aware shortest path selection algorithm.

3. Conclusion:

Since years, UWSN routing methods have been a contentious topic in underwater applications. In this paper, we outline the current state of the study and compare the various underwater routing protocols in great detail. We divide the underwater routing protocols into three groups depending on their characteristics: energy-based, data-based, and geographic information-based protocols. The primary goal of the first class of routing protocols is to increase network energy effectiveness. The effectiveness of data transfer from the source node to the destination node forms the foundation of the second category of routing procedures. The third type of routing protocols is designed to adjust with the changing structure of undersea networks. We examine the offered protocols' protocol techniques, together with their benefits and drawbacks.

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