A Review on Routing Protocols for Underwater Wireless Sensor Networks

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Abstract - *With various underwater applications, including ocean monitoring, seismic monitoring, environment monitoring, and seabed exploration, underwater wireless sensor networks (UWSN) are currently a popular study area in both academia and business. 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. 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. The proposed protocols are thoroughly explained, along with benefits and drawbacks. Meanwhile, a thorough analysis of the effectiveness of several underwater routing protocols is being done. In addition, we discuss the difficulties in the field and potential possibilities for underwater routing protocols, which can aid future study.*

Key Words: Underwater wireless sensor network, Routing protocol, Energy-based protocol, Data-based protocol, Geographic information-based protocol.

1. INTRODUCTION

About 96% of the water on Earth is found in the oceans, which are crucial to human life because they offer natural resources, marine defence, and other advantages. Because of the excessive growth on land, scientists and researchers have focused more on the oceans. Ocean monitoring and research are difficult tasks, despite the abundance of resources in the ocean. The underwater sensor nodes, which are positioned in a specific oceanic region and utilized for data transmission carriers such as radio-frequency (RF), acoustic, and optical waves, comprise the UWSN. However, many wireless communication systems that work well in terrestrial contexts cannot work effectively in underwater environments because of the unique properties of the underwater environment, such as temperature and pressure.

A new network technology made up of sensor nodes is the underwater wireless sensor network. It is mostly utilised for target detection, underwater early warning, and marine environmental element monitoring. In underwater environments, underwater communication is subject to several restrictions. The link quality of these nodes is impacted by additional elements like the Doppler frequency shift and environmental noise interference due to the complexity of underwater channels. The velocity of data transmission, the dependability of data communication, network throughput, and energy usage of underwater networks are all directly impacted by these interferences. Consequently, it is a very difficult challenge to figure out how to send the acquired data swiftly and efficiently to the intended location. In the transmission of network data, route is crucial.

Transmission of data from the network's source node to the destination node is guaranteed by a routing protocol. The underwater sensor nodes have extremely restricted compute, storage, and communication capabilities due to the complex and unstable nature of the underwater environment. Because UWSNs have certain characteristics, such high transmission latency, dynamic structure, and high energy consumption, it is difficult to apply routing techniques designed for terrestrial wireless sensor networks to underwater networks.

2. LITERATURE SURVEY

By gathering and referring to several benchmark studies, a literature review was undertaken.

An adaptive QL-based routing system was devised by Nadeem Javaid et al. [1] in an effort to extend the network's lifespan. QL is mapped to maximize network performance by making completely distributed choices through the deployed agents. Agents are trained using rewards, and each agent's performance in the aquatic environment is evaluated using the computed reward. The suggested routing protocol aims to maximize network lifetime with balanced energy usage by using the QL approach to achieve the maximum reward. Choosing the forwarder node with the most residual energy was made easier by computing the receiver reward at each hop. Additionally, the source node residual energy, which varies after each iteration, is taken into account to avoid repeated selection. This makes it possible for network node rewards to vary and for forwarder selection to change on the fly. Additionally, the data packet is successfully retrieved from the void hole during data transmission by determining the alternative route with the aid of ADN and HN. Despite the fact that this uses more energy, the network throughput has greatly increased.

An energy-aware and void-avoidable routing protocol (EAVARP) was suggested by Zhuo et al. [2]. Layering and data collecting phases are included in EAVARP. During the layering process, sensor nodes are distributed throughout several shells, while concentrated shells are built around the sink node. Periodically, the sink node completes hierarchical duties to guarantee the accuracy and liveliness of the topology. EAVARP is made applicable to a dynamic network environment. Opportunistic directional forwarding strategy (ODFS) is used to advance data packets depending on several concentric shells throughout the data gathering phase, even when there are voids. The ODFS accounts for the residual energy and data transmission of nodes inside the same shell, eliminating cyclic transmission, floods, and voids. The testing and analysis of simulation data demonstrate the superiority of their proposed EAVARP in determining performance matrices when compared to competing routing protocols.

A Q-learning-based localization-free routing protocol (QLFR) was suggested by Yuan et al. [3] and is used for underwater sensor networks to reduce end-to-end latency and extend lifespan. Q-value is derived by jointly taking into account sensor node depth information and residual energy throughout the routing process in an effort to find the best routing rules. To reduce latency and increase network lifetime, we develop two cost functions for Q-learning (depth-related cost and energy-related cost). Additionally, a packet forwarding holding time mechanism is created based on the priority of the forwarding nodes. The three primary contributions are a novel holding time mechanism for packet forwarding, a special Q-learning based routing algorithm for UWSNs, and a packet-delivery ratio-based method to further reduce unnecessary transmissions. Results from extensive simulations show superior performance.

SEECR, or Secure Energy Efficient and cooperative routing protocol, is a suggestion made by Khalid et al. [4] for UWSNs. SEECR has strong defense systems that use less energy to thwart attackers in an underwater environment. Cooperative routing is used by SEECR to enhance network performance. In the context of UWSNs, the proposed SEECR protocol utilizes multi-hop networking by utilizing the cooperation mechanism. In the suggested design, data packets created by the source node are routed, one hop at a time, to the sink or destination node. When there are two successive hops that receive arriving packets, amplify them, and then retransmit them to the destination, the relay node is deployed. The suggested approach effectively removes attacker nodes from the network by detecting frequent active routing attacks that discard packets. In this study, the performance of SEECR is compared to that of AMCTD, a well-known routing protocol for UWSNs that stands for "Adaptive Mobility of Courier Nodes in Threshold-optimized DBR." The outcomes point to SEECR performing better than AMCTD. Some of the main issues that UWSNs must deal with include the hostile environment, longer propagation delays, and the sensor nodes' short battery life. A routing approach known as Reliable Path Selection and Opportunistic Routing (RPSOR) for UWSNs was developed by Muhammad Ismail et al. [5] to overcome these challenges. It is a much improved version of Weighting Depth and Forwarding Area Division Depth Based Routing (WDFAD-DBR).Three primary variables form the basis of RPSOR: the Shortest Path Index (SPi), which takes into account the number of hops to the sink and the average depth of neighbors in the next expected hop; the Advancement Factor (ADVf), which takes into account the depth of the current forwarder as well as the average depth of neighbors in the next expected hop; and the Reliability Index (RELi). Finally, they performed extensive simulations and compared our proposed approach with WDFAD-DBR. The results show that in terms of PDR and energy tax, RPSOR performs better than WDFAD-DBR. However, the suggested method compromises end-to-end latency in sparse networks.

Ying Zhang et.al [6], proposed a reinforcement learning-based opportunistic routing protocol (RLOR) by combining the advantages of opportunistic routing and reinforcement learning algorithm. The RLOR is a type of distributed routing method that carefully weighs the peripheral status of nodes when choosing the best relay nodes. Additionally, RLOR uses a recovery technique to help packets efficiently avoid the empty area and continue forwarding, which increases the rate at which data is delivered in some sparse networks. When compared to other comparable underwater routing protocols, the simulation results show that the suggested RLOR performs well in terms of end-to-end latency, dependability, energy efficiency, and other features in underwater dynamic network situations.

To extend network lifespan, Haseena Gul et al. [7] suggested "an Energy-Efficient Regional base Cooperative Routing (EERBCR) protocol with sink mobility for UWSNs." In which the network field of EERBCR is organized into 12 zones, each measuring three by four both vertically and horizontally. Four mobile sinks in total are placed at equal distances from one another, and 100 sensor nodes are distributed at random. Each mobile sink covers three areas in a predetermined straight course. Until the sink node enters their zone, all sensor nodes are in sleep mode. When the sink node enters a region, it broadcasts a hello message. The message is received by every node in that area, and they all turn on. Another packet is broadcast by the sink just before it leaves the area, alerting the nodes of its impending departure and allowing them to resume sleep mode. The simulation findings demonstrate the effectiveness of EERBCR, as it outperformed the depth and energy-aware dominant set (DEADS), energy-efficient depth-based routing (EEDBR), and depth-based routing (DBR) protocols.

A novel routing protocol called the Geographic and Cooperative Opportunistic Routing Protocol (GCORP) was introduced by S. Karim et al. [8]. Within GCORP, packets are routed from the source node to the surface sinks with the help of intermediary relay nodes. In the GCORP protocol, a network architecture with several sinks is first constructed.. The source node will then choose a relay forwarding set based on the depth fitness factor. Ultimately, the best relay is determined by applying the weight computation technique from the relay forwarding set. The proposed GCORP routing protocol was validated using simulations in NS3 with regard to several network characteristics. The simulations suggest that the GCORP methodology performs better than current methods.

In order to find pareto-optimal routes, Jinil Presis et al. [9] suggested a biobjective optimization of route duration and dependability using an uninformed search approach and a modified greedy best first search heuristic. The biobjective protocol outperforms depth-based, delay-based, and reliability-based routing protocols, according to simulation testing. However, because the biobjective routing issue in underwater wireless sensor networks is known to be dynamic and NP-hard, larger networks require more computing to yield exact answers through uninformed search. The modified greedy best-first search heuristic is used to produce less computationally intensive routes without sacrificing the quality of the answers.

An improved genetic algorithm and data fusion techniques form the foundation of the energy-efficient routing protocol that Umesh Kumar et al. [10] presented. The suggested energy-efficient routing protocol enhances an existing genetic algorithm by adding an encoding strategy, a crossover mechanism, and an enhanced mutation operation that help identify the nodes. The suggested model for an underwater wireless sensor network outperforms existing depth-based routing and energy-efficient depth-based routing approaches.

3. COMPARATIVE STUDY

Table -1: Comparative Analysis

Sl.No.	Study of	Proposed Method	Merits
1.	Nadeem Javaid et al[1]	Adaptive QL based routing protocol	Maximize network lifetime with balanced energy usage by using the QL approach
2.	Zhuo et.al [2]	EAVARP	More effective in selecting performance matrices
3.	Yuan et.al[3]	QLFR	A new holding time mechanism for packet forwarding, and a packet-delivery-ratio-based strategy to further cut down on pointless transmissions
4.	Khalid et.al [4]	SEECR	This approach effectively removes attacker nodes from the network by detecting frequent active routing attacks that discard packets
5.	Ismail et.al [5]	RPSOR	RPSOR outperforms existing WDFAD-DBR in terms of PDR and energy tax
6.	Ying Zhang et.al [6]	RLOR	Performs well in end-to-end delay, reliability, energy efficiency, and other characteristics in underwater dynamic network environment
7.	Haseena Gul[7]	EERBC	Outperforms the depth-based routing (DBR), energy-efficient depth-based routing (EEDBR), and depth and energy-aware dominating set (DEADS) protocols in terms of performance.
8.	S Karim et.al[8]	GCORP	The simulations suggest that the GCORP methodology performs better than current methods.

9.	Jinil Presis et.al [9]	Biobjective optimization	The biobjective protocol outperforms depth-based, delay-based, and reliability-based routing protocols, according to simulation testing.
10.	Umesh Kumar et.al[10]	Energy efficient routing protocol is based on an enhanced genetic algorithm and data fusion technique	Obtained a packet delivery ratio of 86.7%, energy usage of 12.6%, and packet loss ratio of 10.5%

4. CONCLUSIONS

The literature survey was conducted on different works on routing protocol for underwater sensor completed between the years 2018-2023. On conducting the survey different methods there merits and limitations were analyzed and discussed which would be helpful for researchers in the future.

REFERENCES

[1] N. Javaid, O. A. Karim, A. Sher, M. Imran, A. U. H. Yasar and M. Guizani, "Q-Learning for energy balancing and avoiding the void hole routing protocol in underwater sensor networks," 2018 14th International Wireless Communications \& Mobile Computing Conference (IWCMC), Limassol, Cyprus, 2018, pp. 702-706, doi: 10.1109/IWCMC.2018.8450289.

[2] Wang, Zhuo, Guangjie Han, Hongde Qin, Suping Zhang, and Yancheng Sui. "An energy-aware and void-avoidable routing protocol for underwater sensor networks." Ieee Access 6 (2018): 7792-7801.

[3] Y. Zhou, T. Cao and W. Xiang, "QLFR: A Q-Learning-Based Localization-Free Routing Protocol for Underwater Sensor Networks," 2019 IEEE Global Communications Conference (GLOBECOM), Waikoloa, HI, USA, 2019, pp. 1-6, doi: 10.1109/GLOBECOM38437.2019.9013970.

[4] K. Saeed, W. Khalil, S. Ahmed, I. Ahmad and M. N. K. Khattak, "SEECR: Secure Energy Efficient and Cooperative Routing Protocol for Underwater Wireless Sensor Networks," in IEEE Access, vol. 8, pp. 107419-107433, 2020, doi: 10.1109/ACCESS.2020.3000863.

[5] M. Ismail et al., "Reliable Path Selection and Opportunistic Routing Protocol for Underwater Wireless Sensor Networks," in IEEE Access, vol. 8, pp. 100346-100364, 2020, doi: 10.1109/ACCESS.2020.2992759.

[6] Y. Zhang, Z. Zhang, L. Chen and X. Wang, "Reinforcement Learning-Based Opportunistic Routing Protocol for Underwater Acoustic Sensor Networks," in IEEE Transactions on Vehicular Technology, vol. 70, no. 3, pp. 2756-2770, March 2021, doi: 10.1109/TVT.2021.3058282.

[7] Gul, H., Ullah, G., Khan, M. et al. "EERBCR: Energy-efficient regional based cooperative routing protocol for underwater sensor networks with sink mobility". J Ambient Intell Human Comput (2021). https://doi.org/10.1007/s12652-020-02781-7.

[8] S. Karim et al., "GCORP: Geographic and Cooperative Opportunistic Routing Protocol for Underwater Sensor Networks," in IEEE Access, vol. 9, pp. 27650-27667, 2021, doi: 10.1109/ACCESS.2021.3058600.

[9] Persis, Jinil. "A Novel Routing Protocol for Underwater Wireless Sensor Network Using Pareto Uninformed and Heuristic Search Techniques." Wireless Personal Communications 121, no. 3 (2021): 1917-1944.

[10] Lilhore, Umesh Kumar, Osamah Ibrahim Khalaf, Sarita Simaiya, Carlos Andrés Tavera Romero, Ghaida Muttashar Abdulsahib, and Dinesh Kumar. "A depth-controlled and energy-efficient routing protocol for underwater wireless sensor networks." International Journal of Distributed Sensor Networks 18, no. 9 (2022): 15501329221117118.