Enrich, XIV (II): 30 - 37, Jan. - June, 2023

A Survey of Various Types of Routing Protocols for Underwater WirelessSensor Networks

P. Roselin
Assistant Professor, PG Department of Computer Science
A.P.C. Mahalaxmi College for Women

Abstract

Underwater Wireless Sensor Networks (UWSN) has received increased attention from researchers in recent years as a result of their advancement in marine monitoring, application deployment, and ocean surveillance. Underwater wireless communication is the transmission of data underwater via acoustic, optical, electromagnetic, and other means. This article examines existing routing protocols for the building of underwater wireless communication networks. The many forms of routing protocols are thoroughly reviewed, with emphasis on their individual strengths and limitations. This article also discusses challenges and opportunities.

Keywords: Underwater wireless communication; Underwater routing protocols.

Introduction

Oceans comprise approximately 96% of all earth water, which is critical for human survival since it offers natural resources, marine defense, and other benefits. Because of the overdevelopment of land, researchers and scientists have shifted their attention to the oceans. Even with so many resources available in the ocean, ocean monitoring and research are difficult tasks. The underwater sensor nodes are deployed to a specific ocean area, and the self-organizing capabilities of the node is employed for data transmission, forming the UWSN [1]. Communication is the most important network technology. Underwater wireless communication is the transmission of data in a water environment using wireless carriers such as radio-frequency (RF) waves, acoustic waves, and optical beams [2]. Electromagnetic signals, such as RF (radio-frequency) transmissions, decay quickly in water, making practical communications distances hard to attain without a very high-power transmitter. Because this is not feasible for UUVs, wireless underwater communications rely on alternative technologies such as acoustic, optical, and magnetic induction.

Acoustic Communications

Acoustic waves propagate very well underwater and serve as the foundation for the most prevalent type of subsea wireless communications for underwater vehicles. To send and receive signals underwater, UUVs and AUVs can be outfitted with acoustic modems. They also necessitate the use of electro-acoustic transducers, which transform electrical energy from the vehicle into sound energy to be conveyed, or vice versa. While acoustic communications are now the most viable form of underwater communication and have a practical range, they are not without limitations. Due to poor bandwidth and substantial propagation delays caused by the speed of sound in water being thousands of times slower than that of electromagnetic waves in air, acoustic communication networks have a limited capacity for data transmission.

Optical Marine Communications

Additionally, optical systems for line-of-sight (LOS) communication have been developed, often employing laser diodes or LEDs. Compared to acoustic communication, optical communication offers a far faster data throughput and lower latency, but its range is constrained. It can be utilised to enable wireless data recovery from sensors that have been placed underwater by UUV and AUV.

Magnetic Induction

Magnetic coils are used in underwater magnetic induction communication, which has also been created. Although there is nearly no transmission delay with this mode of communication, the range is extremely constrained.

ROV Communications

The most common method of communication with ROVs is a tethered link to the surface. Some underwater robotics will immediately surface if communication is lost. The creation of tether less ROV is currently underway.

Applications for Marine Communications

Marine and subsea communication systems are commonly used to send location data for tracking, mapping, and inspection reasons. They also have the ability to transmit video data and command UUVs. Today, a variety of subsea applications that may require high bandwidth, low latency, bi-directional wireless communication lines can be realised employing intelligent nodes that can wirelessly connect with autonomous underwater vehicles and sit on the bottom. For subsea drones to do complex autonomous tasks underwater, location data sharing is required. For autonomous underwater vessels to support anti-submarine and mine warfare duties in addition to subsea mapping and inspection, secure,interoperable marine communication technologies are crucial.

Real-time Routing Applications in UWSN

- Preventing natural disasters (such as floods, tsunamis, and oil spills)
- Applications with a military focus
- Defence system surveillance,
- underwater enemy movement,
- Coalfields and joint intelligence are some examples.

- Underground Water Pipelines
- Mining of Natural Resources
- Study of Plastic Wreckage and Toxins
- Control of Acidification Pollution

Basically, the Routing Protocols for Underwater Wireless Sensor Networks are categorizedinto the following types,

Reactive Protocols

- It is designed for dynamic environments in which a node initiates the search for aroute to destination nodes
- Despite the fact that it supports dynamic environments, the significant route buildingtime makes it unsuitable for UWSN

Geo-based Routing Protocols

- It uses the node locations to construct the path between the source and the destination
- Addresses how the placements of the nodes are determined

Proactive Protocols

- It is the initial attempt to design routes that results in significant overhead
- Despite the overheads, it strives to decrease the time it takes for data to propagate
- Additionally, the paths frequently alter as a result of node failure or mobility and bandwidth used

Geographic Information-Based Routing Protocol

The geographic information-based routing protocols mainly consider the network andselect the most appropriate path based on geographic information.

Depth-Based Routing Protocol

The depth-based routing protocols do not require the whole geographic position details of the nodes; instead, they simply need to configure the depth sensor to receive the node depth information. The source node finds it simpler to choose the next-hop node and suitable path based on the node depth information thanks to the depth-based routing protocols, which also results in a reduction in network transmission delay and energy consumption. The following is a detailed description of these depth-based methods. DBR [3]: LDBR [4]: For UWSNs, a lightweight depth-based routing protocol (LDBR) is suggested. The LDBR protocol is an expansion of DBR. The LDBR protocol suggests a residual energy-based strategy for reducing energy use in comparison to the DBR technique. The node will broadcast the packet towards the sink node if it has a lower depth and more energy than the preceding node. To extend the lifetime of the network, the LDBR effectively sends the packet to the water's surface while consuming less energy.

Localization-Based

Sensor nodes in underwater wireless networks must be aware of their precise geographic positions in order to use location-based routing techniques. The optimal path confirmation mechanism based on geographic location data is to establish a route using the position information of the nodes, such as angle and distance. Once the source node is aware of the destination node's exact geographic location, it may quickly decide which of its neighbours will serve as the next-hop node for data transfer. The nodes can enhance the efficiency of data transmission by effectively preventing network energy consumption brought on by data packet flooding. Several location-based routing techniques are described in depth in the sections that follow.

VBF [5]: Vector-based forwarding (VBF), a revolutionary routing protocol, is suggested to offer UWSNs reliable and energy-efficient routing. Each data packet in VBF carries the source, destination, and forwarding nodes' positions and a vector inside a routing pipe that connects the source node and destination node determines the forwarding path. A location- based routing technique, the VBF protocol basically sends data from the source to the destination through nodes that are close to the vector. Additionally, VBF employs a self- adaptation method that enables nodes to evaluate the advantages of forging data packets in order to conserve energy.

IVBF [6]: For improving the VBF algorithm, a new algorithm is introduced as IVBF. reduces the radius of the routing pipe to reduce the chance of being selected as the guiding node so that other nodes can have the chance. However, data transmission rates and energy consumption are not balanced in VBF. In the proposed protocol, each data packet contains the location of the source and the destination and the residual energy of the management nodes' energy consumption. The protocol diminishes the range of the routing pipe to decrease the chance of being nominated as the managing node so that other nodes can have the chance to be nominated as the packet promoting node. The protocol could achieve lower energy and higher data packet transmission in the underwater networks.

Localization-Free Routing Protocols

Routing methods that don't require localization don't need to know the sensor nodes' two- or three-dimensional position coordinates. As an alternative, these protocols use pressure sensors to gauge the water's pressure on the sensor nodes, which in turn measures the depth of the sensor nodes. When building the routing paths, the depth of the sensor nodes is used. Through the use of this method, the calculation of the sensor nodes' positions uses less energy and has a shorter propagation delay. When network scalability is required, such as during underwater military operations or when general-purpose marine surveillance is the goal, several protocols are utilised.

Flooding Protocol

The "flood and wait" method is used by flood-based routing technologies to send messages around the network. Typically, they rely on periodically broadcasting messages to all nodes in the network to identify available routes and establish communication between any two nodes. Flooding protocols are straightforward to construct, but because of the enormous volumes of data that must be sent, they can result in severe overhead in big networks. The Simple Flood Algorithm (SFA) is the most widely used protocol based on floods. Nodes should periodically disseminate packets throughout the network until a receiver is discovered in SFA. SFA's key benefit is simplicity because it doesn't call for any prior knowledge of network topology. SFA has the drawback of not taking into consideration transmission direction or distance between nodes, which leads to ineffective routing and expensive overhead. The Hash Flood Algorithm (HFA) is another form of flooding protocol. Although HFA and SFA both rely on periodic packet broadcasts, HFA is different in that it employs hash tables to store previously encountered routes. This lowers overhead by enabling the algorithm to prevent pointless packet resend in a known direction. Additionally, HFA offer more effective routing than SFA because they can take node lengths into account.

Hop-by-hop Routing Protocol

The exchange of messages between two neighbours is the foundation of the hop-by-hop routing mechanism. A routing database that details the path taken by the destination node is kept up to date by each node in the network. The source node transmits a routing request message to its immediate neighbour, who then forwards it to their own neighbour, and so on, until it reaches the target node when a new route to the destination node is required. This strategy works well in networks with many nodes and intricate topologies. Hop-by-hop protocols, however, can be vulnerable to network overload and failure since routing depends on messages being successfully delivered between nearby nodes.

Multihop Routing Protocols

The foundation of multihop routing techniques is message passing between many network hops. To determine the best path between two nodes, these protocols rely on prior information about the network structure. Multihop protocols offer dependable and effective communication across long distances, making them perfect for networks with a lot of nodes and complicated topologies. Multi-hop communication protocols' fundamental drawback is that they are prone to network congestion and outages. Since routing relies on messages being correctly passed between many hops, a single failed link might cause the entire communication channel to break down.

Opportunities and Challenges

Routeing underwater communications offers both benefits and difficulties. On the one hand, because it can travel deeper below, it provides a wider range of options for data transfer. By bypassing surface-based infrastructure, it may also be able to speed up communication and reduce latency. Increased security is another benefit of underwater routing because wired or over-the-air signals are easier to intercept. On the other hand, routing underwater communication presents a number of significant difficulties. First, ship and other vessel noise can interfere with signals, necessitating the use of sophisticated signal processing techniques to resolve these problems. Second, the amount of information that may be conveyed is constrained since the attenuation of underwater signals results in significantly lesser bandwidth available for communication. Finally, compared to terrestrial alternatives, the cost of setting up, maintaining, and updating undersea communication routing nodes is substantially higher. In conclusion, underwater communication routing has advantages in terms of range and security, but it also faces difficulties due to cost, bandwidth constraints, and interference. Future technological developments and improved signal processing techniques may assist to remove these obstacles, creating a fresh window of opportunity for data transfers.

References

[1] H. Luo, K. Wu, R. Ruby, Y. Liang, Z. Guo, and L. M. Ni "Softwaredefined architectures and technologies for underwater wireless sensor networks: A survey," IEEE Commun. Surveys Tuts., vol. 20, no. 4, pp. 2856–2888, 4th Quart., 2018.

[2] Z. Zeng, S. Fu, H. Zhang, Y. Dong, and J. Cheng, "A survey of underwater optical wireless communications," IEEE Commun. Surveys Tuts., vol. 19, no. 1, pp. 204–238, 1st Quart., 2017.

[3] H. Yan, Z. J. Shi, and J.-H. Cui, DBR: Depth-Based Routing for Underwater Sensor Networks, [Lecture Notes Computer Science (Lecture Notes Artificial Intelligence Lecture Notes Bioinformatics)], vol. 4982. Heidelberg, Germany: Springer, 2008, pp. 72–86.

[4] S. Gul, S. H. Jokhio, and I. A. Jokhio, "Light-weight depth-based routing for underwater wireless sensor network," in Proc. Int. Conf. Adv. Comput. Sci. (ICACS), vol. 2018. Lahore, Pakistan, 2018, pp. 1–7.

[5] P. Xie, J.-H. Cui, and L. Lao, "VBF: Vector-based protocol for underwater sensor networks," in IFIP Netwoking. Heidelberg, Germany: Springer, 2006, pp. 1216–1221.

[6] S. M. Mazinani, H. Yousefi, and M. Mirzaie, “A vector-based routing protocol in underwater wireless sensor networks,” Wireless Pers. Commun., vol. 100, no. 4, pp. 1569–1583, 2018.

[7] B.Lobo, D.Crespo, D.Corujo (2019). GBR: a Geo-Based Routing Protocol for Underwater Acoustic Networks. International Journal of Distributed Sensor Networks 15 (8), 1550147719883604.

8] Y.Ly, P.Ghani, A.S.Meryem, A.B.K.A.Aziz, M.A.Rahman, (2020). An adaptive duty cycle based routing protocol for multi-hop underwater acoustic networks. Journal of Network and Computer Applications 153, 102770.

[9] S.Mamaghanian, M.Movahedi, E.Safari (2019). A Multi-Layer Routing Protocol to Support Quality of Service in Underwater Acoustic Sensor Networks. In 2019 15th International Wireless Communications & Mobile Computing Conference (IWCMC), p.1601-1607.

[10] N. Ismail and M. M. Mohamad, “Review on energy efficient opportunistic routing protocol for underwater wireless sensor networks,” KSII Trans. Internet Inf. Syst., vol. 12, no. 7, pp. 3064–3094, 2018.

[11] I. F. Akyildiz, D. Pompili, and T. Melodia, “Underwater acoustic sensor networks: Research challenges,” Ad Hoc Netw., vol. 3, no. 3, pp. 257–279, 2005.

[12] P. Ögren, E. Fiorelli, and N. E. Leonard, “Cooperative control of mobile sensor networks: Adaptive gradient climbing in a distributed environment,” IEEE Trans. Autom. Control, vol. 49, no.8, pp. 1292–1302, Aug. 2004

[13] J.-H. Cui, J. Kong, M. Gerla, and S. Zhou, “The challenges of building mobile underwater wireless networks for aquatic applications,” IEEE Netw., vol. 20, no. 3, pp. 12–18, May/Jun. 2006.

[14] G. Han, J. Jiang, N. Bao, L. Wan, and M. Guizani, “Routing protocols for underwater wireless sensor networks,” IEEE Commun. Mag., vol. 53, no. 11, pp. 72–78, Nov. 2015.

[15] M. Ahmed, M. Salleh, and M. I. Channa, “Routing protocols based on node mobility for underwater wireless sensor network (UWSN): A survey,” J. Netw. Comput. Appl., vol. 78, pp. 242– 252, Jan. 2017.

[16] M. Khalid et al., “A survey of routing issues and associated protocols in underwater wireless sensor networks,” J. Sens., vol. 2017, May 2017, Art. no. 7539751.

[17] M. Fazeli and S. N. Basharzad, “A survey on underwater wireless sensor networks routing algorithms,” in Proc. IEEE 4th Int. Conf. Knowl. Based Eng. Innovat. (KBEI), Tehran, Iran, 2017, pp.373–378.

[18] S. M. Ghoreyshi, A. Shahrabi, and T. Boutaleb, “Void-handling techniques for routing protocols in underwater sensor networks: Survey and challenges,” IEEE Commun. Surveys

Tuts., vol. 19, no. 2,pp. 800–827, 2nd Quart., 2017.

[19] M. Ahmed, M. Salleh, and M. I. Channa, "Routing protocols for underwater wireless sensor networks based on data forwarding: A review," Telecommun. Syst., vol. 65, no. 1, pp. 139–153, 2017.

[20] A. Datta and M. Dasgupta, "Underwater wireless sensor networks: A comprehensive survey of routing protocols," in Proc. Conf. Inf. Commun. Technol. (CICT), Jabalpur, India, 2019, pp. 1–6