International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

E3CORP: Enhanced Energy-Efficient Cooperative Opportunistic Routing Protocol for Underwater Sensor Network Based on Void Node Detection

[1]Ramanjeet Singh, [2]Amit Jain

Submitted: 10/10/2023 **Revised**: 30/11/2023 **Accepted**: 09/12/2023

Abstract: UnderWater Sensor Networks (UWSN) are becoming more popular among researchers due to its unique properties and challanges. However, the ever-changing pattern of water waves presents significant difficulties in the construction of the UWSN system, making it mostly unworkable. By relying on the collaboration of the relay nodes to deliver the data to the surface nodes, the opportunistic routing approach may serve as an efficient option for the UWSNs. Keeping this in mind, we propose a new protocol named, E3CORP. The proposed method consists of four steps: information acquisition, best links forwarding, void discovery, and the optimal data forwarding phase. Using the stated procedures for the proposed method, void nodes are excluded from the routing process, thus improving network performance. Moreover the proposed approach has been compared with exsisting techniques such as GCORP, ERDBR and DBR based metrics like delay, residual energy, lifetime, delivery rate, throughput and energy utilization on the basis of varing node count. It has been observed that the proposed approach is more effective than the exsisting techniques.

Keywords: *Communication void, opportunistic routing, link quality, depth, routing, residual energy.*

1. Introduction

Geographically separate sensors make up Wireless Sensor Networks (WSNs), that act as a network to collect data from the real world. Environmental variables such as temperature, pressure and moisture may be monitored with this sensor. Due to the unique challanges of water, such as noise level, signal loss, temperature, saltiness, and multi-path transmission [1-3], the underwater situation is completely varied from the terrestrial environment. In addition, GPS cannot be utilized for underwater localization because of the system's unique properties and the quick reduction of water waves [4-6].

to the sinks. For UWSN routing protocols, spatial routing models seem to be a more effective and prevalent strategy [7][8]. In UWSN, Communication Void (CV) is a major issue that may significantly affect network throughput and packet loss, particularly in sparse networks. A communication gap occurs when a data packet reaches a region where there are no active sensors to relay the message. In geographical routing, it is not necessarily necessary to change the state of the routing route using the routing information [9-10]. When combined with Opportunistic Routing (OR), geo-opportunistic routing may boost package transfer rates and reduce energy consumption.

Energy may be the most important element for UWSN, since it uses higher level of power for signal transmission than conventional sensor networks. Some of the related works, such as [11-12] and many more [13], do not take energy into account while creating their work. In this regard, one must take into account the energy consumption difficulty in underwater audio communication while designing the suggested routing protocol. Additionally, previous routing strategies rely on flooding techniques [14-15] and a single path to reach the surface sink, which incurs large energy costs, to access the surface sink.

The paper is divided as: Section 2nd covers the literature work pertaining to the OR techniques considering the CV issues. The proposed framework is defined under the 3rd section and then simulation along with metrics are defined in the 4th section. In the 5th section performace of the proposed technique is being done and at last it is ended with conclusion as the 6th section.

2. Related Work

Packet is transmitted from source to destination using the nodes geo location data in a geographical routing scheme. By using the broadcast features of the wireless medium, authors in [16] have been able to obtain an better packet delivery values. A statistic called the Expected Packet Advancement (EPA) was proposed as a way to better balance power usage with increased network dependability. A EMGGR (Energy-efficient Multipath

1University Institute of Computing Chandigarh University Mohali, India
ramanjeetsingh3498@gmail.com
2University Institute of Computing Chandigarh University Mohali, India
amit_jainci@yahoo.com

Grid-based Geographical Routing) method has been developed by Salti et al. [17]. A grid method of routing is used in EMGGR to reduce the delay by slicing up a big packet into smaller ones.

Ghoreyshi et al. [18] describe a Stateless Opportunistic Routing Protocol (SORP) that uses an adaptive forwarding strategy to minimize the empty communication region. Using this method, the vacant communication space may be avoided entirely. In [19], the same author presents a protocol named Opportunistic Void Avoidance Routing (OVAR) for talking the concern of void transmission. The OVAR protocol, on other side, did not consuder nodes leftover energy when selecting the appropriate relay node. So Rahman et al.[20] came up with the Energy-Efficient Cooperative Opportunistic Routing (EECOR) method, where the optimal relay is taken considering the PDP and left over energy from each node using a fuzzy algorithm. Huang et al. [21] showed a Power-Efficient Routing (PER) method that included two phases: the identification of forwarding nodes and pruning of the forwarding tree.

According to [22], a Depth-Based Routing (DBR) technique was presented wherein the node which is forwarding the packets is decided by considering the depth values. The Fuzzy Depth-Based Routing (FDBR) protocol was suggested by author in [23] as a customized form of the DBR protocol. Holding times were calculated using a fuzzy method. Many geo based OR protocols exist, such as VBF through Xie et. al. [24], an improved version named HH-VBF through Nicolaou et al. [25], AHH-VBF in [26] and CVBF in [27], where only those nodes make a contribution to the packet forwarding which exist inside the virtual pipeline and are guided it toward the surface sink [28]. These protocols do not use any technique to fix the energy utilization. Accordingly, Abbas et. al. [29] provide the Energy Balanced Vector-Based Forwarding Protocol (EBVBF). This protocol's major objective is to extend network longevity by balancing underwater node energy consumption.

Another work in [30] proposes a Stateless Opportunistic Routing Protocol (SORP) that identifies empty and stuck nodes internally in various portions of the network topology and eliminates them throughout the routing phase utilizing a passive involvement mechanism. Sun et. al. [31] proposed a new way to locate underwater sensor nodes in a network. They use a mobile anchor node that moves along a planned path on the water surface to help determine the position of the sensor nodes. Liu et. al. [32] propose a new algorithm called VA for locating underwater sensor nodes in a network under complex marine conditions. Pabani et. al. [33] propose a new energy efficient method for forwarding packets in an UWSN. Gautam et. al. [34] propose a new and efficient node deployment model for WSNs. They also present a solution to the problem of locating sensor nodes using the RSSI method. In another work [35] authors have provided the analysis of various energy efficient methods in green IoT for better communication.

3. Proposed Approach

The main intent of thus proposed approach is to devise a reliable routing strategy that can detect the communication void and thus avoid packet loss to large extent. There have been four stages to the proposed method: data collection, best link forwarding neighbors identification, void discovery, and optimum data packet forwarding. Initially, the primary data is disseminated by sending out a "hello" packet to all nearby neighbours. After that, the calculated link quality is included into the routing table. For the next step, we'll use the node with the lowest link cost (route metric). In the third stage, an approach is developed to find the genuine and void nodes. At last datapacket are forwarded through the regular nodes while avoiding the void as much as possible. The whole process has been depicted in Figure 1.

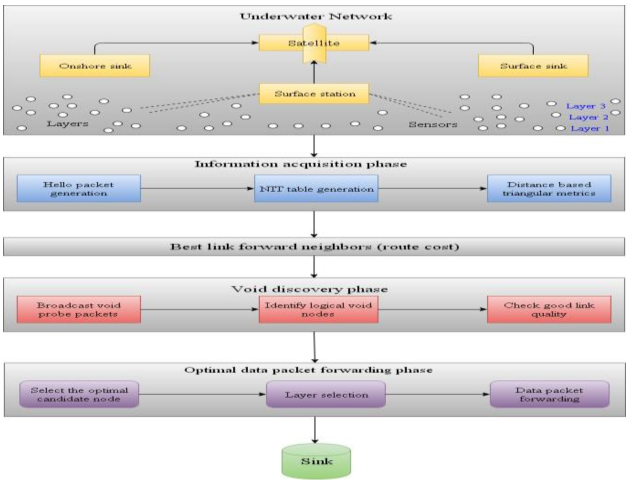

Fig 1: Proposed Framework for the void avoidance approach with phases.

3.1 Information Acquisitionn Phase

One of the main component is Neighbour Information Table (NIT). Each sensor inside a one-hop range has to collect and save data for its neighbours. During the data acquisition and void discovery phases, each sensor may gather data via the transmitted hello packet. Six different pieces of information are stored in the NIT: an identifier (id), a depth value, a residual energy value, a distance calculated using the triangulation concept, a route cost, and a Boolean flag (has Void). Indicating that the node is now vacant, the value of this flag has been modified. In the information-gathering stage, hello packets are routinely used by neighbours to communicate with one another. The sender's identifier (id), a depth value, and a residual energy value make up the hello packet's three fields. In addition, the depth value is utilize to determine the sender's depth.

So, by using the data of NIT table best node is selected and then the distance among the nodes is calculated using the traingulation metrics based on parameters such as Link Quality Information (LQI), Signal to Noise Ratio (SNR) and Packet Recption Rate (PRR). If the hello packet has been received from a neighbour at a lower depth, the receiving node will save that information in its NIT. If not, the message is immediately deleted. The working of this phase has also been represented in the form of algorithm1.

Algorithm1: Data Processing Phase

Symbol	Details
Pi	i^{th} packet
id	Node Identity
depth	Depth of Node
Hp	Hello Packet
re	Residual Energy
TP	Triangular Process

```
Function GenerateHello (Pi)
    If HelloTimeComplete is completed
        Generate Hello Packet (Hp)
            Hp.id ← Pi.id
Hp.depth ← Pi.depth
            Hp.re ← Pi.re
        Broadcast (Hp, Time + randomtime)
            Set NewTime
    End If
End Function
Function  GetHello ( Pi, Hp)
    If ( Pi.depth> Hp.depth)
If  Hp.depth is not in Pi.NIT
        Generate NewFile (new)
            new.id ← Hp.id
new.depth ← Hp.depth
            new.re ← Hp.re
Pi.NIT ← insert (new)
        distance ← distance (Hp.id, Pi.NIT)
            Pi. NIT [distance] . id ← Hp.id
            Pi. NIT [distance] . depth ← Hp.depth
            Pi. NIT [distance] . re ← Hp.re
        End if
        LQI- TP (Pi)
    Else
        Delete (Pi)
    End If
End Procedure
```

3.2 Root Cause Determination

The least expensive option is to have the forwarding node be the one closest to the sink, with enough of available power and a strong connection. However, the Route Cost, which takes into account both energy remaining and quality of link to determine the next node, deviates from the planned minimal cost depending on left over energy and ETX (energy used for transmission). It can be calculated among the the nodes (x,y) as defined in equation 1.

Route Cost (x,y) = (1- Resy / Resmax)+(1- Δd(x,y) / Δdmax) (1)

In this equation, Δd(x,y) is the Link Quality among sender and the forwarder nodes x and y, Resy is the typical value of the left over energy of nodey, and Resmax is overall energy of a node; Δdmax is a maximum distance.

3.3 Void Discovery

Here, the main work is to find the real nodes and void by designing and creating a void discovery approach. In this algorithm, each node check its NIT. If NIT does not have any neighbors, it consideritself as a real void. Therefore, this node generates a void probe consisting of two parts, namely Sender ID and flag named "has_void" with True value (i.e., '1'). Next, it embeds its ID and "has_void" value '1' in the packet and disseminate it to neighbors lying at one hop.

The working of this phase has also been represented in the form of algorithm 2.

Algorithm 2: Void Discovery Phase

Symbol	*Details*
ui	*i^{th}node*
NP	*Void probe packet*
NonVc	*Ordinary node count*
id	*Node Identity*
Loc	*Node location at NIT*
C	*Total nodes in NIT*
hv	*void location in NIT*
Vc	*Void node count*
has_void	*Flag Value*

```
Function ProcessNullPacket (ui)
    If NullPacket TimeComplete is completed
        If ui.NIT is empty
            GenerateHello (NP)
                NP.id← ui.id
                NP. has_void ← '1'
            Broadcast (NP)
        End if
    End if
End Function
Function  GetNullPacket(ui, NP)
If  (NP.id is not in ui.NIT)
        Return
    Else
        Loc ← Identify Loc ( NP.id, ui.NIT)
        ui.NIT [Loc] . hv ← NP.has_void
    End if
        Vc ← 0
        NonVc ←0
    For k=1 to C do
        If (ui.NIT . hv == '1')
            Vc ← Vc+1
        Else
            NonVc ← NonVc +1
        End if
    End for
```

3.4 Optimal Data Forwarding

At this point, the data packet is being sent, and the forwarding algorithm is choosing which nodes to transmit it to. Here, the data-forwarding phase prevents the void nodes from participating in the process. Here, the idea is to filter out the void nodes and choose the best possible candidate node from among the regular ones. The working of this phase has also been represented in the form of algorithm 3.

Symbol Details	Details
C	Route Cost
Δd	Triangular Metric
data	Node Data

```
Function OptimalDataForwarding (ui, datapacket)
If ( ui.id = = data.goodCandidate)
{
        For k= 1 to C do
{
                Rc (i,j) = (1 - Residualj/ Residualmax)
                + ( 1- Δ(i,j)/ Δdmax)
                routecost=  routecost(i,j)
                ui.NIT [j] = ui.insert(routecost)
}
 }
Else
        Drop (data)
```

4. Simulation and Metrics

Our network simulator of choice for testing the E3CORP protocol's functionality and efficiency was a discrete event type network simulator. 3D network area with dimensions of 500m X 500m X 1000m is employed for the simulation, and the nodes range in size from 50 to 25 to 400 dynamically. In terms of mobility, our system's behavior may be classified as hybrid. The RandomWalk 2D mobility model is used to keep the network's relay nodes within the network's boundaries. The details of the simulation aspects are depicted in table 1.

Table 1: Simulation parameters for the proposed approach

Simulation Parameter Taken	Value Taken
Topology	Random (100m)
Area for Deployment	500m * 500m * 1000m
Sink count	2
Node count	25 to 400
Range	100 m
Acoustic speed	1500 m/s
Energy	100 J
Medium Used	Radio Waves
Bandwidth	10 Kbps
Velocity of Signal	1500 m/s
Movement of node	2 m/s, 4m/s
Energy Usage	2w, 0.75w and 10mw
Data Packet Size	100 byte
Bandwidth	4Khz
Depth	10 to 50 m
Time for Simulation	1000 s
Count for simulation Runs	100

We analyzed the following metrics in this study to compare the performance of the suggested strategy to that of the existing approach. Packet Delivery Ratio (PDR), End to End Delay (EED), Packets Transmitted (PT), Energy Consumption (EC), and Network Life Span (NLS) and Residual Energy (RE) are the metrics studied.

5. Performance Analysis

The proposed algorithm (E3CORP) is being simulated under the various metrics that are defined and its efficiency is analyzed. Also it is being compared with the existing algorithm such as DBR [22], GCORP [36] and ERDBR [37] against all the metrics by varying the node count from 25 to 400 as mentioned in the simulation parameters in Table 1 along with other parameters in consideration.

Figure 2 shows the PDR findings at various node densities. In other words, increasing the number of nodes enhances PDR since it extends across a wider area of the network. Compared to other routing protocols, the E3CORP provides a higher value of PDR for both sparse and dense networks. At node count 100, E3CORP is having 2% more PDR as compared to GOCRP, 5% with ERDBR and 10% more effective than DBR.

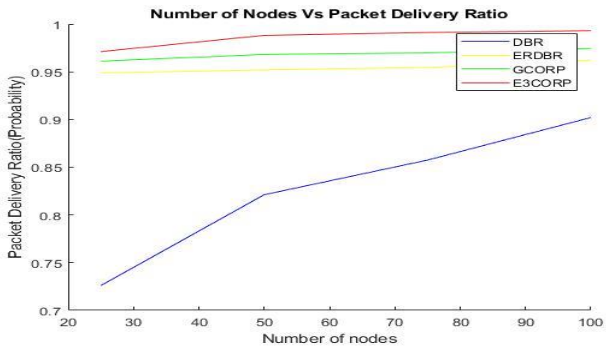

Fig 2: Variation of PDR with node count

The E2E delay for each technique is shown in Figure 3. With each additional node, average E2E latency lowers. When contrasted to other benchmark protocols like DBR, GCORP and ERDBR, the E3CORP protocol has a lower average E2E latency. In the GCORP protocol, the source node chooses its relay forwarding depending on the beacon information it receives from its one-hop neighbours to prevent hidden terminal problems. For the node count 100, E3CORP is having 65% lower E2E latency as compared to DBR, 48% less latency than GOCRP and 38% with respect to ERDBR.

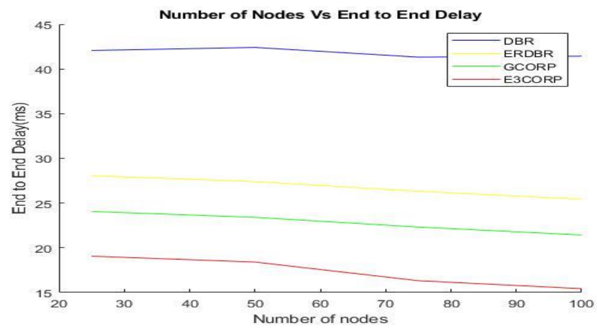

Fig 3: Variation of EED with node count

Node count is shown in Figure 4 as a function of average energy consumption (EC). It has been established that the suggested protocol has superior outcomes for energy consumption than the GCORP and ERDBR procedures because it considers energy metrics more thoroughly during route creation. Also it is being observed that E3CORP consume 20% less EC in contrast to DBR, 7% less EC with respect to GCORP, 9% less EC consumption with respect to GCORP and 11% less than ERDBR.

E3CORP's average NLS is shown in Figure 5 beside DBR, GCORP's and ERDBR's in contrast. Since the average EC of benchmarking methods is higher than the E3CORP method, the NLS of the GCORP, DBR and ERDBR methods is lower than that of the E3CORP protocol, as can be observed.For the 400 node count, E3CORP is having 12% higher NLS in comparision to GCORP, 15% higher than DBR and 5% higher NLS with respect to ERDBR.

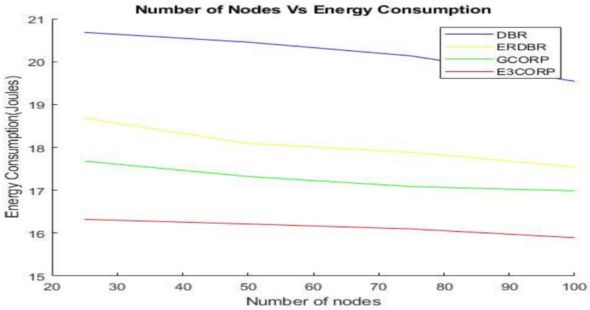

Fig 4: Variation of EC with node count

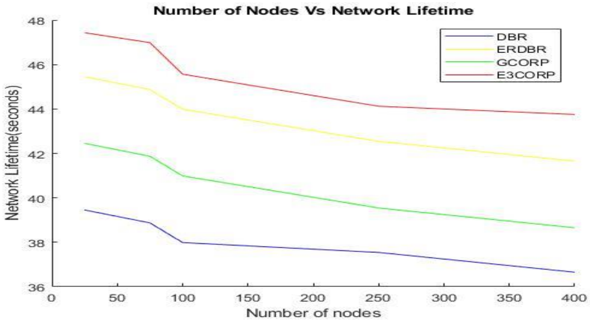

Fig 5: Variation of NLS with node count

E3CORP's packet transmission is shown in Figure 6 beside DBR, GCORP's and ERDBR's in contrast. It can be seen that the PT of DBR, GCORP and ERDBR approaches is lower than that of E3CORP method since the EC is greater for GCORP and ERDBR than the E3CORP protocol, which finally decreases the PT. When the node count is 400, E3CORP is having 30% more packets transmission in contrast to ERDBR, 46% higher PT with respect to DBR and 5% more packet transmission with respect to GCORP.

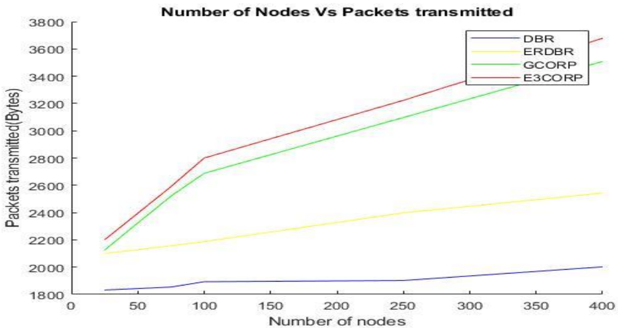

Fig 6: Variation of PT with node count

6. Conclusion

The high energy requirements of UWSNs make it difficult to create a routing system that uses minimal energy. When a data packet reaches an area with no operational sensors, there will be an interruption in communication termed as communication void . This paper introduces the E3CORP methodology where each sensor may collect information throughout the data-gathering and void-detection phases by monitoring for the hello packet. Depth value has also been considered to determine the node depth of the each node. After then, the next forwarding node in the network is calculated on the basis of route cost, which considers both the remaining energy and the link quality. This is followed by a new step where a voiddetection method is created to determine which nodes are genuine and which are void. Finally, a smart data forwarding method has been developed employing knowledge of the void zone to avoid the void region when information is transmitted, resulting in little packet loss. It has been observed that the proposed approach is effective in comparison to existing methods like GCORP, ERDBR by varying the node count under the network metrics. At node count 100, E3CORP is having 2% more PDR as compared to GOCRP, 5% with ERDBR and 10% more effective than DBR. Similarly, E3CORP is having 65% lower E2E latency as compared to DBR, 48% less latency than GOCRP and 38% with respect to ERDBR. Also it is being observed that E3CORP consume 20% less EC in contrast to DBR, 7% less EC with respect to GCORP, 9% less EC consumption with respect to GCORP and 11% less than ERDBR. In the future the integration of machine learning methods will be applied while deciding the optimal route determination

References

[1] I. F. Akyildiz, D. Pompili, and T. Melodia, ''Underwater acoustic sensor networks: Research challenges,'' Ad Hoc Netw., vol. 3, no. 3, pp. 257–279, May 2005.

[2] J. Heidemann, W. Ye, J. Wills, A. Syed, and Y. Li, ''Research challenges and applications for underwater sensor networking,'' in Proc. IEEE Wireless Commun. Netw. Conf. (WCNC), Apr. 2006, pp. 228–235.

[3] R. W. L. Coutinho, A. Boukerche, L. F. M. Vieira, and A. A. F. Loureiro, ''Design guidelines for opportunistic routing in underwater networks,'' IEEE Commun. Mag., vol. 54, no. 2, pp. 40–48, Feb. 2016.

[4] Y. Noh, U. Lee, P. Wang, B. S. C. Choi, and M. Gerla, ''VAPR: Void-aware pressure routing for underwater sensor networks,'' IEEE Trans. Mobile Comput., vol. 12, no. 5, pp. 895–908, May 2013.

[5] M. Jouhari, K. Ibrahimi, H. Tembine, and J. Ben-Othman, ''Underwater wireless sensor networks: A survey on enabling technologies, localization protocols, and Internet of underwater things,'' IEEE Access, vol. 7, pp. 96879–96899, 2019.

[6] M. Ayaz, I. Baig, A. Abdullah, and I. Faye, ''A survey on routing techniques in underwater wireless sensor networks,'' J. Netw. Comput. Appl., vol. 34, no. 6, pp. 1908–1927, Nov. 2011.

[7] M. Jouhari, K. Ibrahimi, H. Tembine, and J. Ben-Othman, ''Underwater wireless sensor networks: A survey on enabling technologies, localization protocols, and Internet of underwater things,'' IEEE Access, vol. 7, pp. 96879–96899, 2019.

[8] M. Ayaz, I. Baig, A. Abdullah, and I. Faye, ''A survey on routing techniques in underwater wireless sensor networks,'' J. Netw. Comput. Appl., vol. 34, no. 6, pp. 1908–1927, Nov. 2011.

[9] D. Chen and P. Varshney, ''A survey of void handling techniques for geographic routing in wireless networks,'' IEEE Commun. Surveys Tuts., vol. 9, no. 1, pp. 50–67, 1st Quart., 2007.

[10] R. W. L. Coutinho, A. Boukerche, L. F. M. Vieira, and A. A. F. Loureiro, ''Geographic and opportunistic routing for underwater sensor networks,'' IEEE Trans. Comput., vol. 65, no. 2, pp. 548–561, Feb. 2016.

[11] P. Xie, J.-H. Cui, and L. Lao, VBF: Vector-Based Forwarding Protocol for Underwater Sensor Networks. Berlin, Germany: Springer, 2006, pp. 1216–1221, doi: 10.1007/11753810_111.

[12] H. Yan, Z. J. Shi, and J.-H. Cui, DBR: Depth-Based Routing for Underwater Sensor Networks. Berlin, Germany: Springer, 2008, pp. 72–86.

[13] T. Islam, Y. K. Lee, ''A comprehensive survey of recent routing protocols for underwater acoustic sensor networks,'' Sensors, vol. 19, no. 19, p. 4256, Sep. 2019.

[14] S. Lee, Y. Bae, M. T. R. Khan, J. Seo, and D. Kim, ''Avoiding spurious retransmission over flooding-based routing protocol for underwater sensor networks,'' Wireless Commun. Mobile Comput., vol. 2020, pp. 1–9, Aug. 2020.

[15] A. Wahid and K. Dongkyun, ''Analyzing routing protocols for underwater wireless sensor networks,'' Int. J. Commun. Netw. Inf. Secur., vol. 2, no. 3, p. 253, 2010

[16] S. M. Ghoreyshi, A. Shahrabi, and T. Boutaleb, ''A stateless opportunistic routing protocol for underwater sensor networks,'' Wireless Commun. Mobile Comput., vol. 2018, pp. 1–18, Nov. 2018.

[17] F. Al Salti, N. Alzeidi, and B. R. Arafeh, ''EMGGR: An energy-efficient multipath grid-based geographic routing protocol for underwater wireless sensor networks,'' Wireless Netw., vol. 23, no. 4, pp. 1301–1314, May 2017.

[18] S. M. Ghoreyshi, A. Shahrabi, and T. Boutaleb, ''A stateless opportunistic routing protocol for underwater sensor networks,'' Wireless Commun. Mobile Comput., vol. 2018, pp. 1–18, Nov. 2018.

[19] S. Ghoreyshi, A. Shahrabi, and T. Boutaleb, ''A novel cooperative opportunistic routing scheme for underwater sensor networks,'' Sensors, vol. 16, no. 3, p. 297, Feb. 2016.

[20] M. A. Rahman, Y. Lee, and I. Koo, ''EECOR: An energy-efficient cooperative opportunistic routing protocol for underwater acoustic sensor networks,'' IEEE Access, vol. 5, pp. 14119–14132, 2017.

[21] C.-J. Huang, Y.-W. Wang, H.-H. Liao, C.-F. Lin, K.-W. Hu, and T.-Y. Chang, ''A power-efficient routing protocol for underwater wireless sensor networks,'' Appl. Soft Comput., vol. 11, no. 2, pp. 2348–2355, Mar. 2011.

[22] H. Yan, Z. J. Shi, and J.-H. Cui, DBR: Depth-Based Routing for Underwater Sensor Networks. Berlin, Germany: Springer, 2008, pp. 72–86.

[23] R. Mohammadi, R. Javidan, and A. Jalili, ''Fuzzy depth based routing protocol for underwater acoustic wireless sensor networks,'' J. Telecommun., Electron. Comput. Eng., vol. 7, no. 1, pp. 81–86, 2015.

[24] P. Xie, J.-H. Cui, and L. Lao, VBF: Vector-Based Forwarding Protocol for Underwater Sensor

Networks. Berlin, Germany: Springer, 2006, pp. 1216–1221, doi: 10.1007/11753810_111

[25] N. Nicolaou, A. See, P. Xie, J.-H. Cui, and D. Maggiorini, ‘‘Improving the robustness of location-based routing for underwater sensor networks,’’ in Proc. OCEANS Eur., Jun. 2007, pp. 1–6.

[26] H. Yu, N. Yao, and J. Liu, ‘‘An adaptive routing protocol in underwater sparse acoustic sensor networks,’’ Ad Hoc Netw., vol. 34, pp. 121–143, Nov. 2015.

[27] C. J. B. Abbas, R. Montandon, A. L. S. Orozco, and L. J. G. Villalba, ‘‘EBVBF: Energy balanced vector based forwarding protocol,’’ IEEE Access, vol. 7, pp. 54273–54284, 2019.

[28] Ghoreyshi, S.M., Shahrabi, A. and Boutaleb, T., 2016. A novel cooperative opportunistic routing scheme for underwater sensor networks. Sensors, 16(3), p.297.

[29] Coutinho, R.W., Boukerche, A. and Loureiro, A.A., 2018, October. PCR: A power control-based opportunistic routing for underwater sensor networks. In Proceedings of the 21st ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (pp. 173-180).

[30] Ghoreyshi, S.M., Shahrabi, A. and Boutaleb, T., 2018. A stateless opportunistic routing protocol for underwater sensor networks. Wireless Communications and Mobile Computing, 2018.

[31] Sun, Y., Yuan, Y., Xu, Q., Hua, C., & Guan, X. A mobile anchor node assisted RSSI localization scheme in underwater wireless sensor networks. Sensors, 19(20), 2019.

[32] Liu, C., Wang, X., Luo, H., Liu, Y., & Guo, Z. VA: Virtual node assisted localization algorithm for underwater acoustic sensor networks. IEEE Access, 7, pp.86717-86729, 2019.

[33] Pabani, J. K., Luque-Nieto, M. Á., Hyder, W., & Otero, P. Energy-efficient packet forwarding scheme based on fuzzy decision-making in underwater sensor networks. Sensors, 21(13), 2021.

[34] Gautam, P. R., Kumar, S., & Kumar, A. An optimized sensor node localization approach for wireless sensor networks using RSSI. The Journal of Supercomputing, pp.1-25, 2022.

[35] Singh, R., & Jain, A. A Study of Various Energy Efficiency Techniques in Green IoT. In 2021 3rd International Conference on Advances in Computing, Communication Control and Networking (ICAC3N), 2021, pp. 596-601.

[36] Karim, S., Shaikh, F.K., Chowdhry, B.S., Mehmood, Z., Tariq, U., Naqvi, R.A. and Ahmed, A., 2021. GCORP: Geographic and cooperative opportunistic routing protocol for underwater sensor networks. IEEE Access, 9, pp.27650-27667.

[37] Neelavathy Pari, S., Sathish, M. and Arumugam, K., 2018. An energy-efficient and reliable depth-based routing protocol for underwater wireless sensor network (ER-DBR). In Advances in power systems and energy management (pp. 451-463). Springer, Singapore