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Opportunity Based Energy Efficient Routing Algorithm for Underwater Wireless Sensor Network for Submarine Detection

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Abstract

The submarine detection is the most significant research area of Under Water Acoustic (UWA) environment with extensive application in commercial and navy domains. The environmental complexity and variable nature of the UWA makes Underwater Wireless Sensor Network (UWSN) to exhibit fluidity, sparse deployment, time unpredictability, frequency selectivity, limited accessible bandwidth and energy constraints pose problems in the underwater positioning technology. Thus, an adaptable, scalable, and highly efficient UWA is required for the submarine routing systems. The depth-based routing has received lots of interest as it is capable of delivering effective operation without requiring full-dimensional position information of nodes. However, it has issues of vacant regions and detouring forwards. To delineate the aforementioned problems, this paper proposes an Opportunity-based Distance Vector Routing (ODVR) technique. The distance vectors, which have lowest hop counts in the direction of sink for underwater sensor nodes are determined by ODVR through a query method. Depending on the distance vectors, a dynamic routing is created to manage the packet forwarding. In the opportunistic forwarding, the ODVR has a minimal signaling cost and minimum energy consumption with the potential of eliminating the long detours issues. The outcomes of simulations demonstrate that the ODVR outperforms the conventional routing algorithms.

Keywords: Submarine Detection; Underwater Wireless Sensor Network; Dynamic Routing; Energy consumption, packet delivery ratio and End-to-End Delay.

1 Introduction

Marine engineering and its consequent technologies are remarkably significant in the operations like underwater topographic exploration, building of marine engineering or resource development and nautical scientific analysis. Underwater operations and submarine detection are essential in marine construction projects including artificial island reef building, submarine recovery, development of tunnel, laying of underwater pipeline and ocean mineral resource research. Currently, the submarine detection technology is applied in deep sea engineering and coastal region. When compared to the conventional satellite navigation and positioning systems, the underwater navigation system with positioning and navigation system is highly considerable. The radio signals are carried over a large distance through a saline at relatively low frequencies in the complex and changeable deep sea environment [1-2]. Only the buoys close to the sea acquire GPS location signal. As a result, establishing underwater positioning UWSNs has evolved as a potential method for locating the underwater environment.

It is used to discover the ocean locations. In addition, it is used in undersea navigation, seismic observation, oilfield exploration, oceanographic surveillance and underwater navigation. In these applications, a monitoring and controlling centers are often established to gather data from multiple sensors that are stationed in underwater to create a UWSN. Hence, the data forwarding and routing from sensors towards the sink is a successful method of submarine detection applications [3], which employ a diverse set of underwater methodologies to create a massive data processing for tracking of resource, data gathering and monitoring. In most cases, a monitor is installed to receive data from UWSN's sensors. As a result, data forwarding and routing from underwater sensors to the sink becomes a critical mechanism of underwater applications. Because of the liquidity feature of the underwater territory, the routing in UWSNs has certain difficulties [4–7]. The underwater wireless communication route suffers from significant signal losses [8] and the complicated multipath effect [9] results in a higher bit error in communication with restricted bandwidth for underwater audio communication [10].

Furthermore, the acoustic channels of underwater have a propagation delay about five orders greater than terrestrial radio channels [11]. On account of the low speed of acoustic signal in water, the communication is subjected to significant Doppler Effect caused by trans-receiver motion or varying surroundings like surface waves, interior disturbance, and speed variations. As a result, the light-weight signaling and flexibility to high-quality dynamic link are required for reliable packet delivery in the underwater wireless communication. For wireless multihop networks with lossy links, the opportunity-based routing algorithms have been proposed to enhance packet delivery ratio and throughput [12-13]. To reduce packet losses, these protocols uses the wireless channel and arbitrary routings for achieving contiguous diversity at the receiver [11-16]. To enhance the lifetime of the network and to elevate the energy efficiency, the energy competent cooperative routing approaches are preferred by various manufacturers and researchers. However, these approaches provide inaccurate results, which minimizes the overall performance in a wider range [17-18].The opportunity routing has been used in UWSNs to combat the high bit error rate in wireless network [19]. The sensor nodes of classical routing mechanisms depends upon the predetermined routing table for forwarding the packets but the protocol selects a group of routing options from adjacent sensors for forwarding the data packets to the sink [20]. As a result, data packets have high chance of being successfully transmitted to the sink.

There are some opportunity-based routing methods in the literature, which are playing a significant role designing the UWSN since these approaches are applied in the operations like data transmission, data tagging and object tracking. In spite of having various beneficial measures, these approaches delivers certain limitations like sensitive towards temperature fluctuations, lesser reliability and inaccurate location detection [21-23]. In consideration with the position information of every nodules, the Vector-Based Forward (VBF) mechanism [24] measures the "routing pipe" and the nodes in this pipe carry the location information of submarine. As a result, the routing pipe towards the destination defines the forwarding path. On the other hand, obtaining position information is regarded as a difficult process in UWSNs. Hence, a Depth-Based Routing (DBR) scheme is employed, in which the pressure sensors are employed to assess the depth of submarine. Based on the acquired depth data, the DBR eagerly sends the location information to the shallow nodes and eventually to the destination on the sea surface. However, the node is unable to identify an appropriate next hop (bottom node) to transmit its data packets in a sparsely distributed network when the greedy hop-by-hop forward approach frequently reaches a void zone [25]. Both wireless networks and acoustic networks have looked at the empty region in opportunity routing. To recover communication from the void region, a protocol that involves relocating the nodes in void areas to new depth is introduced to modify the topology. Though the obtained results of this approach are highly adequate, its applications are limited as it owns the demerits like extreme propagation delay, excessive disruptions or noises, low bandwidth and excess energy consumption [26-28].

Traditional opportunity based routing systems need several signaling exchanges across the sensor nodes to choose the relay candidate set or to select the forwarders and coordinated opportunistic forwarding. The forwarding scheme is easily implemented at each sensor by correlating the depth with the upstream node depth for determining the packet transmission, by which the DBR protocol decreases signaling overhead. However, the empty regions are unavoidable in DBR. As a result, additional overheads are included to cope up with the void region problem like location information in VBF and periodical alarms in VAPR [29-30]. Moreover, it is necessary to divert the packets down to avoid the void zone, which is referred as the long detour issue. The lengthy detour causes packet transfers to be delayed. In order to rectify these issues, the implementation of multimodal Acoustic routing approach is employed, which assists in enhancing the durability of the sensor nodes but fails to satisfy the demand of ideal outcomes with expected standards [31]. An energy efficient distance vector is used in this article to provide opportunistic routing in UWSNs to avoid the void area and lengthy detour issues. Each node's distance vector keeps tracking the count of hop it takes to get into the sink. An OR based distance-vector (ODVR) mechanism is suggested based on the hop-count information to transmit the location information of submarine through the possible shortest path. The remaining parts of this paper is laid out as below. The network model and an outline of ODVR are described in section II. The design of the ODVR is expounded in Section III. The performance assessment of ODVR using the results of simulation software is depicted in section IV and the summation is provided in Section V.

2 Propagation Model

The sensor nodes of submarine collect the position data from the surroundings and send it to the sink node through the multi-hop forwarding. A minimum of one surface sink is utilized on the water surface to get location information of submarine from sensors through the UWSN channel and to conduct the data to the base station through the wireless radio channel. The transmission begins in the water from the submarine to the destination node.

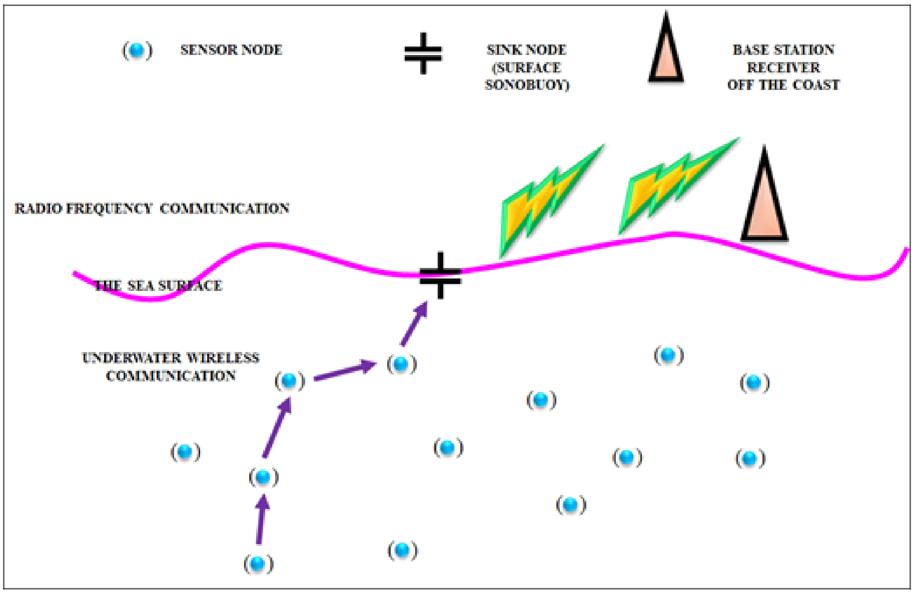

Figure 1: Network model

The expression of energy attenuation in underwater is expressed by,

$$10log(A(l,f)/A_0) = k * 10logl + l * loga(f) \quad (1)$$

Where, the diffusion loss is expressed as k*10logl; absorption loss is defined as l*loga(f); normalizing factor A_0 indicates constant loss; absorption coefficient is a(f); spreading factor k has a value of 2, 1.5 and 1 for spherical, practical and cylindrical spreading. The signal is represented as

$$S_l(f) = SNR(L, f)\frac{(N(f))}{(A^{-1}(l, f))} \tag{2}$$

Where turbulence noise is expressed as N(f).

The power of the signal is specified as,

$$P(F) = \int_{B(l)} (S_l(f)) \tag{3}$$

Where bandwidth is B(l) with l coverage radius

The consumed power [25] is given by The energy consumption of packet [26] is given as,

$$E_p(l) = \frac{(P_r + P_t(l))L}{B} \tag{4}$$

Where L,B,and P_r denote constant, length, transmission rate, and the power required to receive location information of submarine.

When compared to the conventional protocols, the ODVR has several attracting features. The prominent benefits of ODVR are listed in the subsequent section:

Avoids "void region" and "long detour" problems: These common issues in the depth-based routing causes poor packet delivery ratio, extreme delay and high energy usage. The suggested ODVR protocol makes use of the query scheme in UWSNs to determine each node's distance vector to the sink. The location information of submarines is sent towards the destination along with the available shortest route based on the distance vectors. As the distance vector is capable of recognizing the void region, the packets have not reached the empty zones, where the nodes have unlimited counts of hop. At the same time, the shortest-path forwarding strategy of ODVR avoids the lengthy detour.

Light-weight signaling with opportunistic routing: The ODVR requires no complicated signaling from the query method to determine the distance vector of underwater nodes. The ODVR chooses the relay possibilities and coordinates opportunistic forwarding on the basis of the distance vector in each node hop-by-hop node. Unlike the conventional OR protocols, the ODVR requires no information about its neighboring sensors and requires no relay candidate to be included in packet headers. If the location information reaches an intermediate node, the receiver makes a decision to reject or resend it on the basis of the distance vector. Furthermore, the source nodes require no information about the nodes, which have successfully received the location information and about the candidates who have the ability to forward location information. Therefore, the ODVR is proved to be a light-weight protocol with low signaling overhead and few signaling exchanges.

In the multi-hop routing and forwarding, the ODVR makes use of distance vectors. Unlike the typical routing systems, the ODVR has not transmitted the hop by hop location information through a predetermined path. On the other hand, the ODVR takes advantage of any opportunity to relay packets. The ODVR uses distance vector to pick the possible nodes and organize the packet forwarding as the distance vectors have high reachability chances to the sink.

The query technique is used by ODVR to create distance vectors for all sensors. In contrast to the wireless ADHOC networks, the sensor in UWSNs points a certain sink. Only the sink initiates control messages (inquiry packets) and the distance vectors of the sink are stored by the UWSN nodes. As a result, the overhead in control and buffer storage is considerably decreased. The distance vector's hop-count is used by ODVR to determine each node's relay priority. The node with the fewest hops to the sink gets the greatest priority in forwarding the location information. As a result, the ODVR uses distance vectors in nearby nodes to consider all of the neighboring nodes in the possible hop list. In this case, it is not mandatory to include the information about the relay candidates in the headers of data packets, which are transmitted by the sensor sources. The data packets from the sensor sources are simply broadcasted to the sink node as destination.

3 Design of proposed routing protocol

The ODVR creates distance vectors on a regular basis. The submarine begins the routing through the transmission of location information, which is then opportunistically forwarded to the destination by intermediary nodes. The details of ODVR are presented in the subsequent section.

3.1 Establishment of Distance Vector

To assists in the creation of distance vectors, the query mechanism is used in UWSNs. As the sink is the common endpoint for all sensor nodes in UWSNs, the sink is necessary to start the establishment process of distance vector.

The sink: The sink creates query packets on a regular basis and broadcasts the location information to the sensors. Figure 2 shows the query packet header, in which the Query ID is a positive integer that starts at 1 and increments by one. As a result, the Query ID of the most recent query packet is always biggest. The field n keeps track of the distance from the sink as hop count. At the sink node, the field n is initialized to be zero. **Underwater nodes:** Except the sink node, all nodes have a local buffer for recording the sink's distance vector. Unlike the conventional distance vector routing, the UWSNs nodes share the same destination. In addition, the forwarding path is not defined in ODVR. Hence, keeping track of the destination and successive hop are not essential. The Query ID and number of hops to the destination in ODVR are recorded in the local buffer by using the distance vector. The hop count is initialized to infinity by the node in the buffer. When a query packet is received, the local Query ID and number of hops are refreshed.

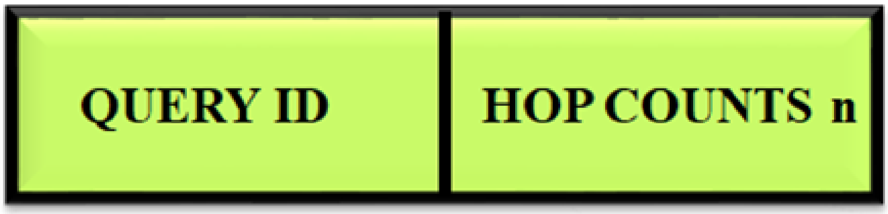

Figure 2: Query packet header

The algorithm given below describes the steps involved in receiving a query packet.

Steps involved in receiving a query packet

Location Information:
The qID *query packets are arriving* and n is the hop count;
The QID_i is a local distance vector and N_i is the node (N is initialized to ∞);
initialize
    if $qID_i > QID_i$ then
        $qID \leftarrow QID_i$;
        $N_i \leftarrow n_i + 1$;
        The query packet is rebroadcasted by setting $n \leftarrow N_i$;
    else if $qID_i = QID_i$ and
        if $N_i > n + 1$
            $N_i \leftarrow n_i + 1$;
        transmit the query packets;
    else
        drop the query packets;
    stop
stop

The above step is continued till the query packets are passed to all the nodes. The shortest path towards the sink is established with the fewest hop counts by all the nodes that access the query packet. If new queries fail to update the distance vectors, these vectors are deleted.

3.2 Routing and Sending at Sources

The opportunity based routing picks several possible relay candidates to forward data packet rather than picking a node sequences along a route for forwarding the data. To help the opportunity based forwarding among the possible relays, the sender has to choose and send through the relay hops with the data packet header, which incur a significant cost for the routing protocol. The ODVR has not picked and sent relay hops in the data packet header to decrease overhead. Instead of picking relay candidates from the source, the ODVR takes use of neighbor node cooperation to create a distributed relay candidate set. Without any control messages, the source simply delivers the data packets. All data packet contains ID of starting node, sequence number of packet, the preceding forwarder's hop-count np and data payload as illustrated in figure 3. The sequence number of packet and source ID are called as Global Packet ID (GID) as these two are used to identify the packet.

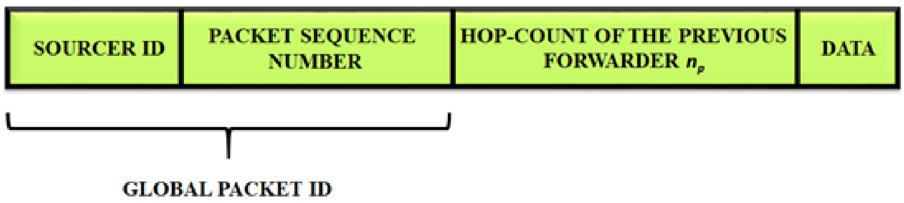

Figure 3: Structure of data packet

When there is no accessible route to reach the destination, the distance vectors reject the useless transmissions. A node in the UWSN gets separated from other nodes due to factors like wave motion, mobility of nodes or energy depletion in certain nodes. The sink sends no query packets to this node. This isolated node's distance vector has an unlimited hop-count. It has to remain quiet to avoid transmission power wastage. When it receives another inquiry packet, it starts the transmission of data packets.

3.3 Opportunistic Forwarding at Intermediate Nodes

It is highly possible for all the neighboring nodes to relay the packets as the sender has not specified the forwarder but some neighboring nodes fails to successfully acquire the packets since the variation in link quality reduces signal. The nodes having shorter links have a better chance of successfully receiving data packets whereas nodes having longer links merely have a lesser chance. To attain a high delivery ratio, the conventional routing schemes take advantage of multi-hop short connections. Despite the low reception probability of lengthy connections, some adjacent nodes are closer to the destination.

It appears that taking use of lengthy adjacent nodes, which have poor successful packet reception speed up the data packet delivery. The nodes' distance vectors are used by ODVR to enable opportunity based forwarding by long adjacent nodes.

The hop count distance and delivery level of data packets from buffered distance vector to the sink are determined by each node. The problem lies in the un-awareness of nearby node, which has successful packet reception of surrounding nodes that have the copies of same packet. The network congestion and transmission overlap arise when all nodes are permitted to send the successfully received packets. Moreover, it maximizes the UWSN's energy usage and bandwidth. The intermediary sensors have to coordinate with one another to prevent repeated forwarding for minimizing the energy wastage and bandwidth. The problem with coordinated forwarding is that the intermediate node has no idea about the distance of possible relay candidates. However, a large number of control messages in UWSNs are not desired.

The distance vectors created by the query method in figure 6 are dependent on the successfully received query packets. The query packet is straightly received from the sink by the red nodes (N = 1). The packets are then passed to the blue (N = 2) and green (N = 3) nodes. Due to the frequent change in UWSN channel, the sink receives the location informations directly from these nodes. When a green node send a packet to the sink, it is no longer required for the blue or red nodes to conduct the similar packet. As a result, the waiting mechanism has to be served for two purposes. The first is to provide data packets to the closest nodes a high priority and then to stop sending the duplicate packets of the same nodes. To achieve opportunity based forwarding, the ODVR utilizes the following timer setting, i.e.,

$$t = 2 \cdot [N_i - n_p + 2]^+ \cdot t_0 + rand(0, CW) \cdot t_slot[N_i - n_p + 2]^+ \tag{5}$$

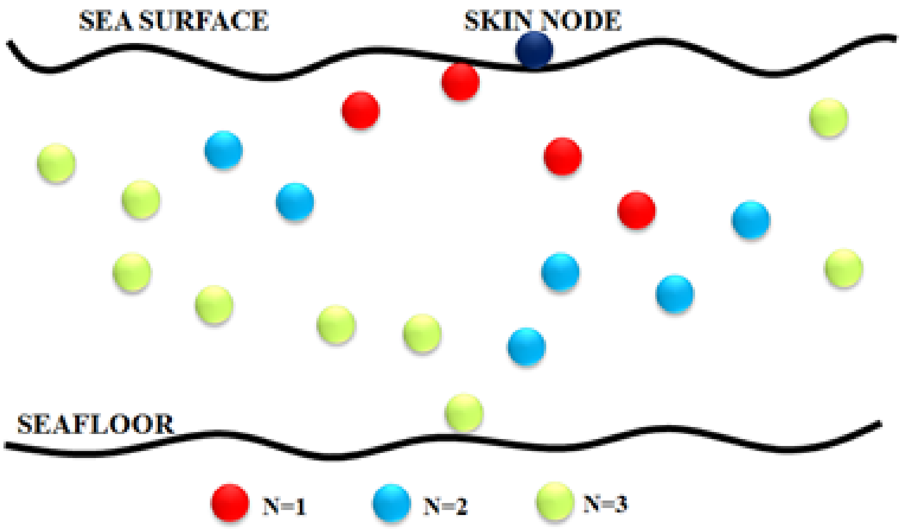

Figure 4: UWSN Query mechanisms

As the nodes wait for fewer than two hop counts away from the destination, the setting in (1) cause no considerable delay in packet delivery because the chances of successful packet delivery after more than two hops are small. Thus, the ODVR assigns highest priority to packet forwarding for nodes, which have more than two hops.

The below Method summarizes the features of the data forward algorithm for the intermediate nodes. The GIDs of formerly acquired data-packets are recorded in two buffers, Q_1 and Q_2. Here, Q_1 is assigned for packets, which are waiting to be forwarded whereas buffer Q_2 is assigned for packets that have already been forwarded. To avoid repeated forwarding, the incoming packet has to be dropped once it has received in Q_1 and Q_2. If not, the node begin a waiting timer with a duration determined by the user (1). The node changes the packet header's hop-count n_p with its own hop-count N_i and then sent the packet when the timer is expired. The node waits to receive packets throughout the waiting time. To avoid redundancy, it rejects a packet if similar packets are sent by a closer node.

According to the ODVR algorithm, a packet telecasted by a node with a hop count N_i is observed by several intermediary nodes with a hop count smaller than N_i. On the other hand, the waiting scheme gives the higher significance to the node having the fewest hops by waiting for lesser period. The ODVR allows no nodes with the similar hop count to transmit packet consecutively in a flooding manner.

The media access control for shared-channel UWSNs prevents several nodes from using the channel simultaneously. When one node is connected to the channel and transfers a packet, the surrounding nodes hear it and cease forwarding the same copy. Furthermore, the random back off avoids causing severe conflict in the media access control by delaying data forwarding in various nodes at random. It's worth noting that the ODVR protocol easily extended for numerous sinks applications. The query packets has to be sent by several sinks. The underwater sensors have to keep track that how many hops it takes to reach any of the sinks. When a packet reaches an intermediary node, it is handled in the similar way as when it arrives at a single sink.

ODVR protocol based forwarding of data packet

Location Information:
distance vector of buffered node N_i;
acquired data packet with GID p_d and hop count n_p;
Q_1 be the set of GIDs of packets
Q_2 be the set of GIDs of packets.
start
    if $p_d \in Q_1 \cup Q_2$
        omit the packet p_d;
    else
        Buffer the packet *pd* in Q_1;
        Set a waiting timer and fix its duration using (1);
    end
    repeat
        if *overhearing of the packet with GID* k_d *occurs, the hop counts* n_d & $n_d \leq N_i$ then
            Discard the waiting timer;
            Neglect the packet p_d;
        else
            Transmit the overhead packet k_d
        end
    until *The waiting timer is timeout*;
    if *The packet* p_d *is not overheard* then
        Change the hopcount n_p with N_i;
        Apply the packet *pd* into Q_1 for forwarding;
    end
end

4 RESULTS AND DISCUSSION

The proposed ODVR is employed in NS2 simulator to assess its performance in an optimal way. Around 200-400 nodes are employed arbitrarily in a space of 1000m * 1000m * 1000m. The comparative analysis of the proposed ODVR with other existing approaches like of Adaptive Power Controlled Routing Protocol (APCRP) and Distributed Energy Efficient and Position-aware (DEEP) routing algorithm in terms of average hop-count, energy consumption, average end-to-end latency, Packet Delivery Ratio (PDR) and time consumption is carried out to measure the submarine detection performance of UWSN. Both the APCRP and DEER algorithms are implemented in the recent works because of having the advantageous impacts like high performance with optimal outcomes. In order to validate the present study in an enhanced manner, the performance of this proposed approach is analogized with these recent algorithms. Hence, it is proved that the present methodology is significantly competent even than the other recent approaches.

The overall consumed energy is highlighted in Figure 5. When the nodes are increased, the overall consumption of energy is also gets maximized. The energy consumption of ODVR is highly lower than the APCRP and DEEP algorithms. Among these three approaches, the APCRP owns high energy consumption because it requires extreme energy for setting up the node power to a high level when it is unable to locate a relay node before transferring the data packets. The packet collisions cause the cross layer node to be identified as a relay node, which makes the APCRP to consume more energy. The sensor nodes in APCRP and DEEP transmit probe packets to identify the relay nodes before transmitting the data packets, which causes extreme energy consumption. On the contrary, the ODVR uses the method of directional forwarding to determine the optimal relay node, which highly assists in minimizing the consumption of energy. Furthermore, the ODVR prevents cyclic transmission to save the overall energy. Thus, it is proved that both the APCRP and DEEP consume significantly more energy than ODVR. The investigation of end-to-end latency is depicted in figure 6. It is observed that the end-to-end latency of APCRP and DEEP is highly greater than the ODVR. The delay of nodes is substantially decreased in ODVR because the nodes deliver data packet instantly to the reliable node. To minimize the latency, the ODVR eliminates cyclic transmission, which is regarded as one of the significant features of this ODVR. When the DEEP or APCRP find it difficult to locate the proper

Simulation Parameters

PARAMETERS	VALUES
Transmission model	ns2: Uan Prop Model Thorp
Underwater channel model	ns2: Uan Channel
Energy Consumption	ns2: Acoustic Modem Energy Model
Signal to noise ratio model	ns2: Uan Phy Calc Sinr Default
Sound speed underwater	$1500m/s$
Transmitted Power	$2W$
Received power	$0.75W$
Transmit power	$2W$
Network boundary	$1000m\ x\ 1000m\ x\ 1000m$
Runtime	$2000s$
Size of Packet	256 bytes
Size of packet header	64 bytes
Opening energy of each node	$500J$
Opening energy of sink node	$1000J$
Transmission range	$150m$
Data transmission rate	$15kbps$
Number of nodes	$200 - 400$
Number of sinks	3

relay node for delivering data packets, the ODVR repeatedly transmit probe packets until it locates the proper relay node. The DEEP has a longer average end-to-end latency than APCRP because DEEP transmits probe packets continuously until it finds an acceptable relay node whereas the APCRP picks a relay node by changing power levels of sensor nodes to reduce latency. Hence, it is validated that the performance of ODVR for the end-to-end latency is significantly greater than others, which clearly represented in the aforementioned figure. For different nodes quantity, the average hop-count of dispatched packet is shown in figure 7. The ODVR has the lowest average hop-count than APCRP and DEEP. In APCRP, the forwarder is chosen on the basis of sensor node depth information without considering the datum from the destination. The packets are transmitted more quickly to the shallower nodes. Furthermore, the lengthy detour problem occurs with APCRP as the shallow nodes are too far from the destination node. In ODVR, the nodes that are close to the destination (in hop-count) are more likely to send the location information with greater priority. Hence, the ODVR frequently sends packets through the shortest route with fewer hops. The packet delivery ratio of APCRP, DEEP and ODVR are compared in figure 8, which indicates that the ODVR outperforms DEEP and APCRP in terms of delivery ratio. The APCRP shows comparatively least performance than others. The sensor nodes in APCRP simply forward the data packets from deep to shallow. If a packet reaches a node that has no accessibility and shallow neighbor, it reaches a void area, which leads to packet loss. Furthermore, the horizontal distance is not taken into account in APCRP. Even if the packets are sent to nodes at the water's edge, the packets get vanished when the sink node is out of coverage area. As a result, the APCRP delivery ratio is restricted specifically when the quantity of destination nodes is low. As the location information is directly transmitted to the sink nodes, the delivery ratio is very high in ODVR and the nodes that are close to the sink are given more priority. The sensor node's forwarding priority is related to its depth in DEEP. As a result, the DEEP has a lower delivery ratio than ODVR. The relation between network lifetime and simulation running time is portrayed in Figure

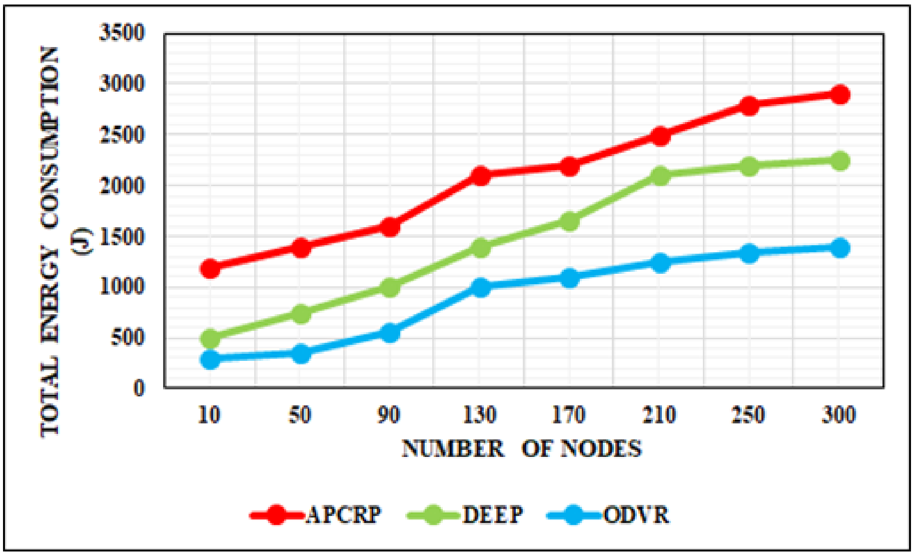

Figure 5: Energy Consumption

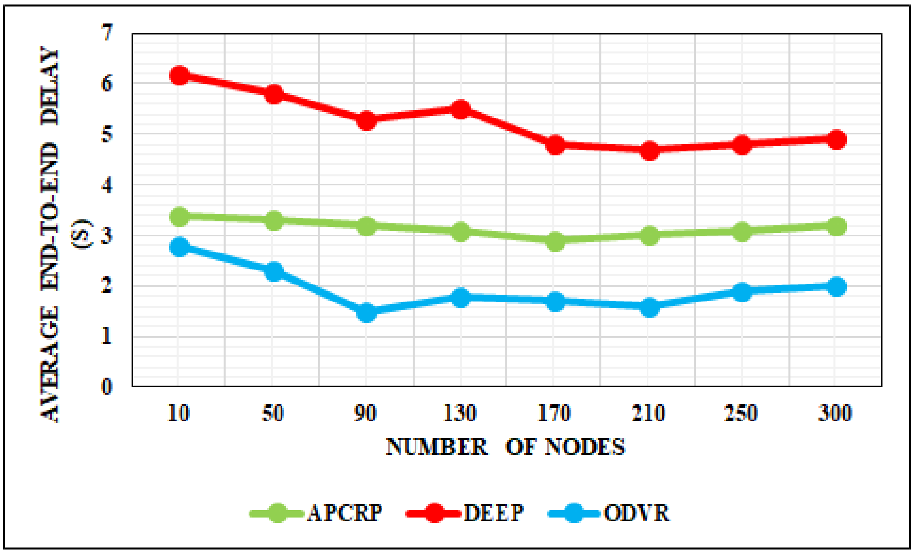

Figure 6: End-to-End delay

9. The network lifespan of sensor nodes begins to decline in the simulation progresses. The network degradation rate of sensor nodes in APCRP is quicker than DEEP and ODVR when the simulation time is below 500s because the senor nodes in APCRP has not identified relay nodes for transmitting data packets. Hence, more power is utilized until the best relay node is identified. Furthermore, the cross layer node is treated as relay node in APCRP due to the packet collision. The aforementioned factors cause certain nodes to use excess energy, which results in making a wide gap between the residual energy and the network's average residual energy. Because of these reasons, the durability of the sensor nodes get minimized in a wider range. The network lifetime degradation rate of DEEP is below 20% at the end of the 900s. Moreover, the ODVR's network lifespan is higher than APCRP and DEEP because the ODVR considers the sensor nodes' residual energy to prevent cyclic transmission and so the energy is distributed to balance the network lifetime. As the residual energy of each node in ODVR falls below the minimal energy, the network is paralyzed at the end of its lifetime. Finally, it is shown that the ODVR's energy distribution are balanced than DEEP and APCRP.

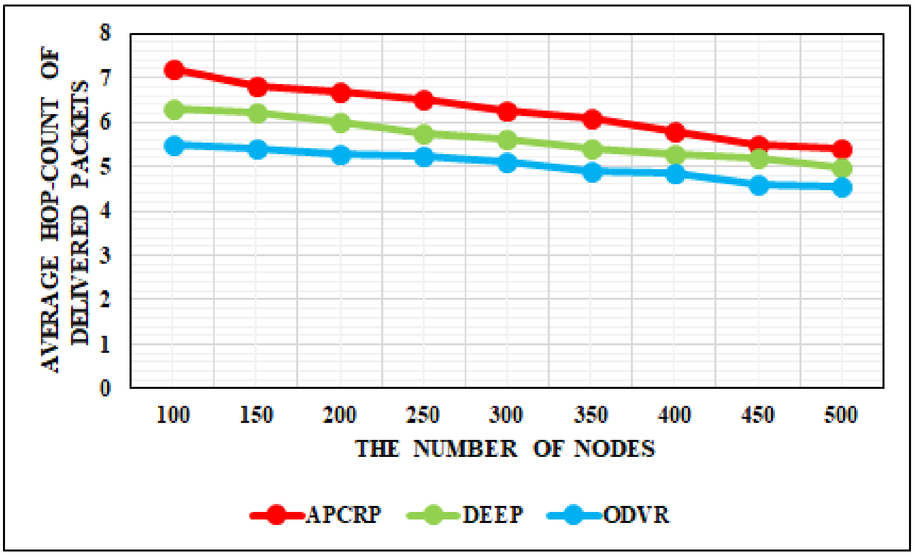

Figure 7: Average hop count

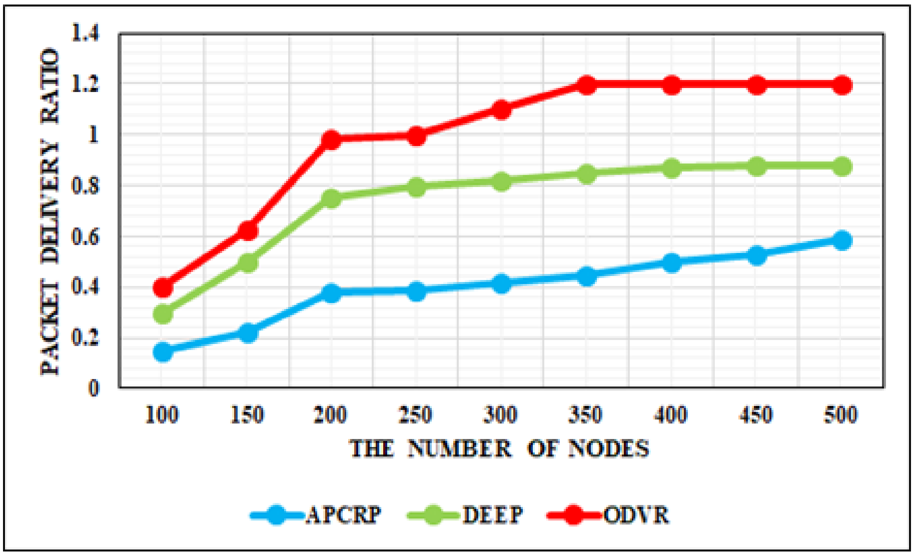

Figure 8: PDR

5 Conclusion

A novel routing algorithm called ODVR is proposed in this paper for the submarine detection using UWSNs. The ODVR uses query method based distance vectors to enable forward routing without any complicated signaling in the process of identifying the submarine and coordinating the packet forwarding among the possible relays. The ODVR topology is legitimate and capable of operating in an environment with dynamic network. The identification of each node is taken into account to characterize the sensor nodes' transmission capacity for eliminating the communication void regions and long detours during the process of forwarding the location information. Furthermore, it assists in delivering the energy efficient routing. Thus, the performance of proposed routing protocol is proved to be superior to the existing DEEP and APCRP methods.

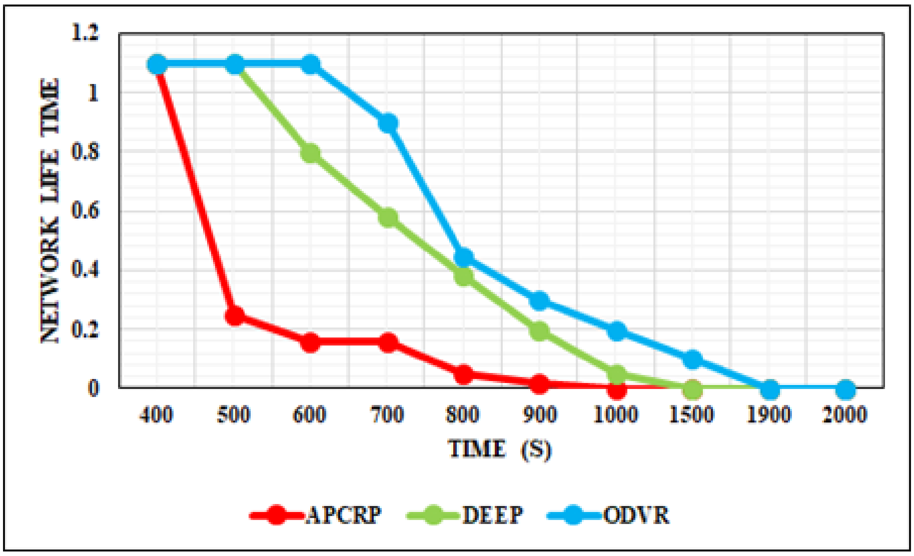

Figure 9: Network lifetime

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflict of interest

The authors declare no conflict of interest.

References

[1] J. Kong, J.-H. Cui, D.Wu, and M. Gerla, "Building underwater ad-hoc networks and sensor networks for large scale real-time aquatic applications,"in Proc. IEEE Mil. Commun. Conf. (MILCOM), Oct. 2005, pp. 1535_1541.

[2] M. K. Watfa, T. Nsouli, M. Al-Ayache, and O. Ayyash, "Reactive localization in underwater wireless sensor networks," in Proc. 2nd Int. Conf.Comput. Netw. Technol., Apr. 2010, pp. 244_248.

[3] G. Han, Z. Tang, Y. He, J. Jiang, and J. A. Ansere, "District partition-baseddata collection algorithm with event dynamic competition in underwater acoustic sensor networks," IEEE Trans. Ind. Informat., vol. 15, no. 10, pp. 5755_5764, Oct. 2019.

[4] Khan, A., Ali, I., Ghani, A., Khan, N., Alsaqer, M., Rahman, A. U., & Mahmood, H. (2018). Routing protocols for underwater wireless sensor networks: Taxonomy, research challenges, routing strategies and future directions. Sensors, 18(5), 1619.

[5] Y. Cui, J. Qing, Q. Guan, F. Ji and G. Wei, "Stochastically optimized fountain-based transmissions over underwater acoustic channels," IEEE Transactions on Vehicular Technology, vol. 64, no. 5, pp. 2108-2112, 2015.

[6] Li, N., Martinez-Ortega, J. F., Diaz, V. H., & Fernandez, J. A. S. (2018). Probability prediction-based reliable and efficient opportunistic routing algorithm for VANETs. IEEE/ACM Transactions on Networking, 26(4), 1933-1947.

[7] Z. Wang, G. Han, H. Qin, S. Zhang, and Y. Sui, "An energy-aware and void-avoidable routing protocol for underwater sensor networks," IEEE Access, vol. 6, pp. 7792-7801, 2018.

[8] S. Coate an and A. Glavieux, “Design and test of a multicarrier transmission system on the shallow water acoustic channel,” OCEANS ’94. ’Oceans Engineering for Today’s Technology and Tomorrow’s Preservation.’ Proceedings, Brest, 1994, pp. III/472-III/477, vol. 3.

[9] Liu, J., Wang, Z., Cui, J. H., Zhou, S., & Yang, B. (2015). A joint time synchronization and localization design for mobile underwater sensor networks. IEEE Transactions on Mobile Computing, 15(3), 530-543.

[10] Y. Haitao, N. Yao, and J. Liu, “An adaptive routing protocol in underwater sparse acoustic sensor networks,” Ad Hoc Networks, vol. 34, pp. 121-143, 2015.

[11] Y. Chen, F. Ji, Q. Guan, F. Cheng, and H. Yu, “Adaptive RTO for handshaking-based MAC protocols in underwater Acoustic networks”. Future Generation Computer Systems, vol. 86, pp. 1185-1192, Aug. 2018.

[12] Ismail, M., Islam, M., Ahmad, I., Khan, F. A., Qazi, A. B., Khan, Z. H., ... & Al-Rakhami, M. (2020). Reliable path selection and opportunistic routing protocol for underwater wireless sensor networks. IEEE Access, 8, 100346 100364.

[13] 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.

[14] Bai, W., Wang, H., He, K., & Zhao, R. (2018). Path diversity improved opportunistic routing for underwater sensor networks. Sensors, 18(4), 1293.

[15] Lu, Y., He, R., Chen, X., Lin, B., & Yu, C. (2020). Energy-efficient depth-based opportunistic routing with q-learning for underwater wireless sensor networks. Sensors, 20(4), 1025.

[16] Rahman, M. A., Lee, Y., & Koo, I. (2017). EECOR: An energy-efficient cooperative opportunistic routing protocol for underwater acoustic sensor networks. IEEE Access, 5, 14119-14132.

[17] A. Yahya et al., "Cooperative Routing for Energy Efficient Underwater Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 141888-141899, 2019.

[18] 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.

[19] S. H. Bouk, S. H. Ahmed, K. Park, and Y. Eun, “EDOVE: energy and depth variance-based opportunistic void avoidance scheme for underwater acoustic sensor networks”, Sensors, vol. 17, no. 10, pp. 2212, 2017.

[20] Li, Y., Cai, K., Zhang, Y., Tang, Z.,& Jiang, T. (2019). Localization and tracking for AUVs in marine information networks: Research directions, recent advances, and challenges. IEEE Network, 33(6), 78-85.

[21] Al-Salti, F., Alzeidi, N., & Day, K. (2020). Localization Schemes for Underwater Wireless Sensor Networks: Survey. Int. J. Comput. Netw. Commun, 12, 113-130.

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

[23] N, Javaid, A. Sher, W. Abdul, I. A. Niaz, A. Almogren, A. Alamri, “Cooperative opportunistic pressure based routing for underwater wireless sensor networks”, Sensors, vol. 17, no. 3, pp.629, 2017.

[24] Mazinani, S. M., Yousefi, H., & Mirzaie, M. (2018). A vector-based routing protocol in underwater wireless sensor networks. Wireless Personal Communications, 100(4), 1569-1583.

[25] Alfouzan, F., Shahrabi, A., Ghoreyshi, S. M., & Boutaleb, T. (2018, August). An energy-conserving depth-based layering mac protocol for underwater sensor networks. In 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall) (pp. 1-6). IEEE.

[26] Li, N., Martínez, J. F., Meneses Chaus, J. M., & Eckert, M. (2016). A survey on underwater acoustic sensor network routing protocols. Sensors, 16(3), 414.

[27] J. Luo, Y. Chen, M. Wu and Y. Yang, "A Survey of Routing Protocols for Underwater Wireless Sensor Networks," in IEEE Communications Surveys & Tutorials, vol. 23, no. 1, pp. 137-160, Firstquarter 2021.

[28] R. W. Coutinho, A. Boukerche, L.F. Vieira, , A. A. Loureiro, "GEDAR: geographic and opportunistic routing protocol with depth adjustment for mobile underwater sensor networks", 2014 IEEE International Conference on Communications (ICC), 2014, pp. 251256.

[29] Sajid, M.; Wahid, A.; Pervaiz, K.; Khizar, M.; Khan, Z. A.; Qasim, U.; Javaid, N., "SMIC: Sink Mobility with Incremental Cooperative Routing Protocol for Underwater Wireless Sensor Networks," EEE International Conference on Complex, Intelligent, and Software Intensive Systems, IEEE, 2016..

[30] Manal Al-Bzoor.; Yibo Zhu.; Jun Liu.; Reda Ammar.; Jun-Hong Cui.; Sanguthevar Rajasekaran, "An adaptive power controlled routing protocol for underwater sensor network," Int. J. Sensor Networks, 2015, 18.

[31] H. Luo, X. Xie, G. Han, R. Ruby, F. Hong and Y. Liang, "Multimodal Acoustic-RF Adaptive Routing Protocols for Underwater Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 134954-134967, 2019.

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