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Research Article

A Novel Hybridized Cluster-Based Geographical Opportunistic Routing Protocol for Effective Data Routing in Underwater Wireless Sensor Networks

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Underwater wireless sensor nodes comprise hundreds to thousands of battery-operated sensor nodes with limited bandwidth. These networks are employed to transmit the data with enhanced quality of service (QoS). However, efficient data routing is the most challenging obstacle in many underwater applications. To solve the issues in underwater sensor nodes, the hybridized cluster-based geographical opportunistic routing protocol with distance vector establishment has been proposed to transmit the data efficiently. Primarily, the proposed methodology finds out the shortest path with minimal hop count whereas the void node can be updated with infinite hop count. Thereafter, the sleep/wake scheduling and waiting mechanism and periodic beaconing algorithm are incorporated into the proposed model to attain a higher packet delivery ratio with minimal energy consumption. This proper scheduling and optimal cluster routing enhance the continuous data transmission in underwater applications. The simulation result reveals that the proposed method achieves better energy efficiency and higher network lifetime when compared with the existing clustering methods.

1. Introduction

Ocean covers two-thirds of land and still the major portion of the underwater environment is in research because it is the most interesting and evocating technology that explores to increase the interest in underwater acoustic sensor networks. Nodes in underwater are widely used to sense, collect, and aggregate all the oceanographic information as data packets in the network layer and to transmit the information from the source node to surface sonobuoys. Acoustic ranging sensor nodes are implemented for finding the underwater location with vertical and horizontal X, Y, and Z positions based on measuring the time it takes for acoustic signals and sound waves to travel from a source to a targeted sensor node. These acoustic ranging sensor nodes emit the signals to the sea bed or ocean surface by allowing the sensor nodes to estimate the positions based on the time of the signal. By knowing the speed of sound and the time of sending and receiving the information in water, the distance to the target accurately calculated the location. By controlling the ocean drift current, acoustic ranging has been seriously monitored. The main responsibility of UWSN is to enable an extensive application in ocean exploration, monitoring activities of aquatic animals, security applications, and pollution monitoring [1, 2].

High-frequency signals such as electromagnetic radiation and optical signals are not suitable for underwater sensor networks. EM waves are highly introduced due to a large variable delay, propagation delay and electromagnetic radiation. So, there may be a high chance for severe attenuation and poor transmission data in the environment. At the same time, optical waves also introduced a high scattering and more absorption in underwater during the transmission of data packets. To overcome these issues, an acoustic wave is used to send the information from the source node to the surface sonobuoy because it is feasible technology in underwater wireless sensor networks. It contains a greater number of sensor nodes which are used to gather all the oceanographic information and to transmit the data through an acoustic wave with the help of sensor interface units. The bandwidth of the acoustic wave is extremely low, and it ranges from 1 Hz to 100 kHz so it needs more power to transmit the data for long-distance communication [3].

During the time of data transmission, it faces various challenges such as high propagation delay, maximum Doppler Effect, high power consumption, high path loss, and noise due to salty water. To overcome the above problem, researchers are designing a new routing protocol to improve the efficiency with minimal power consumption during the time of data transmission. In the acoustic environment, various routing protocols are deployed to boost the relaying efficiency with minimal delay and less power consumption in a greedy manner. According to this perspective, there are three different types of routing protocols are categorized such as proactive, reactive, and geographic [4, 5]. The proactive protocol establishes the routing path and frequently changes the routing table based on the network topology. A reactive protocol modifies only the data for a specific sensor node and updates with a specific routing table without changing the overall network topology. The limitation of this reactive protocol took a long duration to forward the data from the source node towards the sink node.

It often selects the first available route that meets certain criteria, which may not always result in the most energy-efficient or reliable path for underwater sensors. It involves flooding the network with route request (RREQ) packets to find a path to the destination and leads to high control message overhead which is highly problematic in underwater environments with limited bandwidth. Most of the researchers currently undergoing research in reactive protocol to reduce the low latency and slow propagation along with poor QoS in underwater environments [6, 7]. In order to overcome the limitation, a geographic routing protocol is proposed in this work. It has the specific advantage of routing the data packet and forwarding it to the sink node over a sea surface with a vertical link to discover and route the path for the normal node and void node.

Instead of using traditional approaches for finding the path, it specifically finds the exact location and switches over to recovery mode based on the construction of network topology. It does not have any required data to establish a routing table from source to destination and does not require any signalling exchange mechanism with dynamic change in the network topology when the mobility is high. It is a very promising protocol to detect the present position of the sensor node based on the shortest path, hop count, and other network parameters creating a routing decision for enhancing the improved quality of service (QoS) for underwater sensor networks [8]. In this contrast, this proposed method introduces a distance vector implementation with a clustering mechanism to find and transmit the data with minimal hop count and the shortest greedy path. The main contributions of the proposed model are as follows:

(1) A distance vector-based geo-opportunistic routing protocol with a clustering mechanism is proposed with a new routing protocol to improve the performance of QoS
(2) If the clustered data is transmitted over a non-communicating range or a sensor node with minimal amount of energy is considered as a void node or dead node
(3) This methodology finds out the shortest path with minimal hop count whereas the void node can be updated with an infinite hop count
(4) The hop count with infinity valued nodes is considered as void node or useless node, and there is no communication takes place between the void sensor node and the normal node
(5) By implementing the methodology in underwater sensor network will enhance the packet delivery ratio with reduce average energy consumption

2. Related Work

In this section, various recent routing underwater wireless sensor networking protocols have been proposed by researchers in recent years are discussed as follows.

Guan et al. presented an opportunistic routing protocol based on a distance vector to employ the query mechanism for transmit data using hop count. This opportunistic protocol records the distance for each and every node in the underwater environment. The long detour problem occurs extremely in the long transmission range and leads to time delay. This OR routing protocol helps to eliminate a void region and long detour problem. If the packet is not forwarded to a shallower node or neighbour node, it is considered as a void region. At this time, there may be a high chance that the packet may be lost or retransmitted again to the source node. This DVOR can record the distance based on next hop (NH) and next count (NC) in the designed network topology. It creates the shortest distance path with all the sensor nodes to update and exchange information regularly with the relay nodes and periodic table regularly [9]. During this process, it can select the shortest distance path with the least hop count with high priority to forward the data packets from sender to receiver. In this sense, this DVOR cannot transmit a packet to all the relay nodes, and it simply broadcasts the hello message to all the sensor nodes and checks the distance vector establishment with the least hop count. In this work, the least hop count is considered the shortest distance path. If the data depart at an intermediate node, the receiver node will check whether the data packets are need to be discarded or rebroadcasted through opportunistic forwarding to avoid the void problem and long detour problem. Sink periodically generates the query packet to all the nodes because the query packet contains the sequence number and query ID. The query packet sends a hello to all the nodes and finds the shortest distance to all the nodes, and then, it can transmit data through opportunistic routing protocol with the least hop count. By selecting a relay candidate from the source node will broadcast the information to the sink node without any control message to stop the unnecessary transmission. The main limitations of this DVOR need to focus on a long detour problem, and it takes more complex signalling exchanging which leads to limited network lifetime in large-scaled networks.

Khalid et al. [10] proposed an (E^2MR) efficient protocol to increase the energy efficiency and to avoid high power consumption and duplication of packet copies. Improving network lifetime is the major challenge in an underwater network environment. During the time of transmission N, a number of data packets are transmitted from one hop to another hop based on the initial phase and setup phase. During the initial phase level, the source node forwards the request the data packet to all the sensor nodes. If the receiver receives the hello packet to the source node, it will reply with a hello message to all the nodes. The sensor node contains all the information such as depth rate, energy, node ID, and distance. Higher depth rate data in the node will drop the data packet, and lower depth rate is a highly prioritized node to transmit the data from source to sonobuoys. It will avoid flooding of data packets, and the creation of duplicate packet copies during the time of transmission. In the setup phase, the source node forwards the data packets, the nodes that lie within the 25 m range. It directly sends the data packets to the sink node under the calculation of RSSI. Highly prioritized values with fixed intervals periodically update the status of entire sensor nodes via a priority table. The data are forwarded to the entire sensor node if the threshold value is reached during periodic updating. If the data are not being transmitted, all the nodes will go into sleep mode. This protocol is mainly used to enhance the holding time which is mainly dependent on the residual energy. The major limitation of this protocol is it does not support dynamic topology so the stability of the network lifetime will be comparatively less when compared to other protocols.

Khalid et al. [11] proposed a radius-based courier node to improve the efficient energy and reliability of USWN. Various parameters are incorporated along with the radius-based architecture for long-term monitoring of networks with a high packet delivery ratio. Depending upon the radius in the network area, it divides the network area into a sink node to coordinate along with the courier node and static node to deliver data packets efficiently. In this work, the network design is formed as a circle area, and it contains both the sink area and node area. Under this construction, the quadrant portion is considered a sink area, and the remaining is considered a node area. Furthermore, the node is divided into the static node and courier node. Finally, the sink node is accessed as a path by the node, and it is equally divided in a triangular manner. Each triangular node is subdivided into the track, and it is named as T-ID, S-ID, and C-ID. The static ID will remain the same whereas T-ID will change frequently because of movements that occur in USWN. Initially, the node contains a priority table to broadcast the message to the entire sensor node. After a certain time, it will reply back to all the sensor nodes to avoid flooding of data and multiple copies of data packets. If the static node is present within the range of the courier node, it forwards the data packet to the C-ID node to the sink node or else the courier node will search other static nodes to forward the data packet. The major limitations of this protocol are computational, analytical complexity is very high, it consumes more energy, and it cannot able to identify the depth rate in the sensor nodes.

Su et al. [12] described an article based on deep Q-network and latency awareness to improve a network lifetime with the on-policy and off-policy methods. The maximum Q-value in the node forwards the data based on depth and energy with different communication stages in both unicast and broadcast manner to decrease the network overhead. Furthermore, the topology in the acoustic network will change the address based on the on-policy method to choose a different routing decision if the current route becomes corrupt. The deep Q-learning network in machine learning is to optimize autonomous agents. This QL along with the neural network is worked under the Markov chain process, to handle the entire problem such as environmental model random transition. The current state selects the actions of agents to determine the fixed state and next state, which is feedback to the rewarded signal after accepting the current state and next state. QL stores all the Q-values, and it does not support too many states. A deep Q-learning network with DQELR protocol transmits the current information such as residual energy and depth rate. In this work, a source node broadcasts the information from one neighbour's node to another node under the calculation of Q-values to reduce energy consumption to save storage space and time. The node with RE and depth information automatically forwards the information from one node to a neighbouring node using DQN techniques. After getting all this information, it calculates the Q-value and makes an agent in the optimal routing decision. The major limitation of the proposed algorithm is computational complexity is too high.

Faheem et al. [13] presented a paper to enhance the quality-of-service (QoS) and to overcome the poor PDR, bitrate in existing protocol. All the sensors are placed in different depths under 3D-modelled architecture. All the randomly deployed sensors have the same potential in terms of energy and range, which directly communicates along with surface sonobuoys. Each sensor node can know its exact location and its position, and the nodes are moving in a horizontal location and slightly move in the vertical direction under symmetric conditions. Each sensor node dynamically adjusts the low and high transmission range under the CSMA mechanism. In this methodology, a cluster head is used to define a routing path, and it contains a nonnegative integer. The length of the routing path varies accordingly based on the CH node. If the CH node is greater than the number of CH node, it will try to avoid loops in the routing path. At that time, the cluster head lists the node ID depending on topological information from the constructed routing table. The alternate partial routes greedily connect the CH node to the destination and generate the information to transmit data with minimal distance which is finally accepted as a final route. After selecting the routing path, each cluster node maintains the history of the neighbour node and reduces the same rate of dissipation in the energy to the CH node being elected twice for multicast routing strategies. After deploying several sensor nodes, the surface sonobuoys are the only incharge of overseeing an evolutionary algorithm to establish the initial population and number using a random number generator to increase the robustness, which disseminates the packet copies. After receiving information from the sink node, it is responsible for distributing the initial message to one hop or two hops under the CSMA mechanism. For every, successful delivery packet the receiver will broadcast the acknowledgment to the sender node and maintain all the information under the quality parameter. Finally, it selects the parents to recombine the creation of offspring under the selection of the CH node. The nonoverlapping selection of the CH node is preserved for future generations. It will generate the crossover and gives a mutation under a perfect probability for computational efficiency. The major limitation of the routing protocol is to utilize more energy, and it takes a long time to generate the CH under a crossover cluster.

Yan et al. [14] described a depth-based routing protocol to handle depth rate whereas the depth node contains a pressure sensor node to forward data in a greedy manner to handle the network dynamic topology without any assistance from the localization service. The data packet in DBR contains all the depth information and forwards the packets from one hop to another hop. It communicates data from the source node to the sink node based on depth information and does not require full-dimensional position information. In some scenarios, it deploys a sparse number of sensors to transmit data in a hop-by-hop manner. During the hop-to-hop transmission, the nodes frequently enter the void region and cannot find the next hop to drop the packet n in a particular area. Under this forwarding strategy, this DBR protocol can reduce the signal overhead. Deployment of multiple nodes forwards the data from one hop to another node consumes more power and it is incapable of discover a void node. Each packet maintains the priority table and carries a packet sequence number. The main limitation of this protocol is it compares the depth rate to transmit the information from one node to another node, and at that time, it cannot find a void region, and it needs to transmit data without any shortest path, which occurs long detour problem in a long path. This protocol introduces more end-end delay under packet transmission, and the node may simultaneously receive several copies of packets.

Baranidharan et al. [15] proposed a geo-opportunistic routing protocol based on the clustering technique to recover a void region under topology control. This cluster-based OR protocol routes the packet with the help of clustering. It calculates the new depth to utilising the void sensor recovery algorithm. Based on the depth adjustment mechanism, it works in a vertical direction. Each node identifies its own location and determines its X, Y, and Z coordinates. This clustering technique controls the void node and enhances the periodic beacon message to identify its location, and also, it elects the cluster head based on the cluster head selection algorithm. Each node generates a periodic beaconing message based on the sequence number and unique ID and query ID. This query ID transmits data only to particular selective nodes to reduce the time delay and improve the low energy consumption. These sequence numbers are not compatible with sonobuoys and sensors for synchronisation. These numbers can be used to locate the most recent beaconing sequence number and broadcast the data packets to all the sensor nodes. The selection of clustering nodes in C-GEDAR mainly depends on the shortest in order to enhance the network lifetime. By acquiring a hop-to-hop communication, the data packets are transmitted through an intermediate node which provides residual energy whereas each node creates its unique ID for the relay mechanism to transmit a message to the end of the selected hop member. The major limitation of this C-GEDAR is if the generation of the data packet may take a long time on the receiver side, it will produce continuous beaconing before sending the data.

Ahmed et al. proposed a (CBE2R) cluster-based routing protocol to transmit data based on a clustering mechanism [16]. It contains two nodes such as an ordinary node and a courier node. At the ocean's bottom, ordinary nodes are randomly placed in a three-dimensional manner. The courier node is placed with seven number of layer between courier node and another node that forward the data packets. It contains three phases such as cluster formation phase, route development, and data transformation phase. In cluster formation, the courier node contains 8 layers. When compared to ordinary nodes, the cluster head contains high battery power and memory power. So, the courier node is preferred to select the best cluster head node. The bottom layer of the cluster head node transmits and joins all the received messages with less than a 4-hop count distance. The message format contains CH ID, alive time, energy level, hop count, and hop ID. The cluster head ID is the permanent ID for all the sensor nodes to recognize their own sensor node with every neighbour node. After the completion of cluster head formation route development and establish a route from the CH node's weighted value of adjacent node to the source node. This route development phase gives high priority with a high-weighted value. After completing the route development phase, the source node will deliver the data packets through the designated customized path to the courier node. The courier node will collect every bit of data and relay it to a separate courier node with the largest amount of power.

Rodolfo et al. [17] described a routing protocol called geo-opportunistic routing protocol to identify the void region based on its own location and its depth. This GEDAR transmits data based on the topology of the network and depth rate. If the packet enters an out-of-networking region (i.e., the void region), it should attempt to be forwarded using some rehabilitation methods. In this proposed work, the sensor nodes are deployed in Euclidean space, which is working in the vertical direction. All the sensor nodes identify their depth through the sink node. All the sensor nodes contain a graph that is not directed with time and a set of vertices. During initialization, each and every sensor node has the same amount of energy. A collection of nodes with the distance (d) forward data packets under forwarding selection procedure and greedy manner over a long-distance communication. If a node is identified as a void region during data packet transmission, it automatically switches to recovery mode, and if the node is dependent on the network topology, it forwards data directly. The major limitation of this proposed work is it consumes more power during the retransmission of data.

Perumal et al. [18] proposed a paper on extending network consistency for intra and interzone in wireless sensor networks. In this work the proposed algorithm a Hybrid HSA-MMFO algorithm and hybrid Moth Harmony Memory (MHM) algorithm are used to produce a new vector along with all available vectors and list the number of ZH among the nominee nodes and decided optimal path decision. At the same time HSA method, HMCR and PAR gave new solution to optimize the global optimum results. With the help of HSA, the dynamic feature of MMFO enables exploring across several search regions while enhancing search efficiency in each search zone and also reduces the energy consumption in each node. The parameters such as hop count (HC) and residual battery energy (RBE) are available in the ZH path. Any sensor node that has a larger RBE than the current ZH is referred to as ZH. Then, in each set, the existing ZH is transformed into a standard ZM. Even though ZH maintained a standard ZM, RBE signifies the remaining battery energy level of the node after performing some rounds of communication.

The rest of the article is configured as follows. Section 2 explains problem formulation, Section 3 describes a system model and overview and working methodology of clustered DVGOR, Section 4 provides the simulated result and its discussion, and finally, in Section 5, a conclusion is provided.

2.1. Problem Formulation. In this context, the existing work model is an opportunistic routing protocol with a distance vector to forward the data packets from the source node, and it is determined by a number of hop and location of the next hop along with shortest path. The void region in terrestrial networks is usually fixed because it is a static sensor node whereas underwater sensor nodes are dynamic which moves from one place to another place. So, it is one of the most challenging issues in UWSN. In each node, the distance vector keeps track of how many number of hops made toward the sink node as part of the query mechanism. This existing work is mainly focused on finding the shortest path with the least hop count without focusing on finding a void node or dead node. It cannot be focused on improving the QoS whereas it considers the void node also for creating the shortest path. When compared to DVGOR along with existing routing protocols such as DBR, DVOR, and DVGOR, the QoS (i.e., packet delivery ratio and average energy consumption) needs to be improved. This DVGOR needs further optimization and enhancement to improve the packet delivery ratio with average energy consumption. To overcome the limitations, a new improved methodology called distance vector-based geo-opportunistic routing protocol is used along with the clustering mechanism.

3. Network Model

This section gives a detailed description of the network model for clustered DVGOR. From Figure 1, it clearly shows that the system model for underwater sensor network (UWSN) architecture along with the sensor nodes is distributed randomly across the entire region. It collects the oceanographic information as a data packet and forwards it from the source node to the sonobuoys within the communication range. This system architecture consists of the limited number of surface sonobuoys, and a massive amount of mobile nodes are randomly placed on water's surface. By using a geo-opportunistic routing protocol, each node communicates along with the adjacent nodes and broadcasts the beaconing message periodically to identify its own location.

$$\begin{aligned} N &= (N_n . N_s) UCR, \\ N_n &= N_1 + N_2 +, \ldots, \frac{N_n}{n}, \\ N_s &= S_1 + S_2, \ldots, \frac{S}{N_s}, \end{aligned} \tag{1}$$

where N_n represents the number of sensor nodes deployed in underwater, N_s represents the number of sink nodes deployed over an ocean surface, and UCR represents nodes within communication range. Each and every sensor node contains a very limited bandwidth (i.e., range from 1 Hz to 100 kHz). Consider the underwater propagation range with velocity $V = 2.054$ m/min, energy $E = 1500$ mJ/m for power, and X, Y, and Z coordinates to identify the own location of sensor nodes [19, 20].

3.1. Proposed Method of Clustered DVGOR. This article's main contribution clearly shows that the geo-opportunistic routing protocol with a clustering mechanism for improved QoS (i.e., packing delivery ratio with minimal energy consumption).

(1) Every sensor node is aware of its own location, and it contains a query ID, sequence number, node ID, and X, Y, and Z location

(2) If the node is required to send information as a data packet, the sensor node will act as a router to forward the data with the suitable shortest path in a greedy manner

(3) The node will always prefer to select the relay candidates for data transmission-based communication range and shortest distance along with the least hop count

(4) The distance vector is outlined as hop count and next hop whereas the combined form of both geographic and opportunistic routing protocols is to enhance

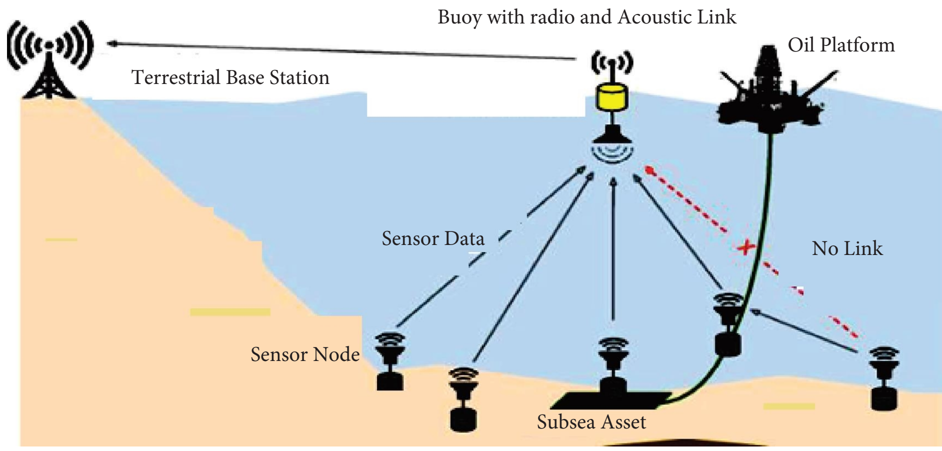


Figure 1: System model of underwater sensor network.

the overall efficiency of packet delivery ratio with average energy consumption [21]

(5) DSR and AODV are some of the distance vector-based routing protocols that are used to record the distance from the forwarding node to the receiving node

In this methodology, the position-based routing protocol determines the qualified adjacent node, which continues to forward the gathered information as a data packet. The routing protocol in clustered DVGOR will be able to broadcast the enhanced beaconing message periodically to all the sensor nodes. It is used to determine the position of all the sensor nodes by obtaining local information from the source node to the sonobuoy. After completion, each node establishes the distance vector to determine the hop count. Each node should record and update the distance vector for each and every node when changes occur in the next hop and hop count. By using the query ID, it utilizes the calculation for finding the number of hops. Generally, routing protocols are often used to establish the shortest path for multihop forwarding and routing the data. After the completion of distance vector establishment, all the nodes start to create and elect the best cluster head and form the n number of cluster sets by using cluster head selection and cluster set formation algorithm based on o initial weight [22]. Figure 2 clearly represents that the UW sensor routes the data packet with an efficient clustering mechanism whereas the cluster head with the least hop count gives the highest priority to forward the data packet from one cluster head to another CH. After the completion of the cluster head election and formation algorithm, it forwards the data packets to the next-hop forwarder. It selects one clustered set to another clustered set to transmit the data by improving the packet delivery ratio with minimal delay.

3.2. Enhanced Periodic Beaconing Algorithm. Periodic beaconing plays a major role in all routing protocols. It obtains the local information (hop count) from all the adjacent nodes and sends the information to surface sonobuoys. It advertises the sensor node's position, hop count, and location from the source node to sonobuoys. Enhanced periodic beaconing message handles all the received beaconing messages e_{pB}, and it contains the query ID, node ID, sequence number, and X, Y, and Z positions.

$$\begin{aligned} &N_s * 2(a+b) + 2_a + 3_b, \\ &e_{\mathrm{pB}=\infty}, \end{aligned} \tag{2}$$

where a and b represent the size of the sequence number, node ID, and X, Y, and Z coordinates, respectively. It is not necessary to synchronize all of the sensor nodes and surface sonobuoys with the sequence number in the beaconing message. The depth information of sonobuoy is eliminated from the beaconing message because it works under both horizontal and vertical movements and broadcasts to all the adjacent nodes.

3.3. Finding the Shortest Path Using Enhanced Periodic Beaconing Algorithm. Normally, sensor nodes sense all the information as a data packet in the network layer and send it to the sink node through relay nodes. During the time of transmission, it finds the shortest route and transmits the information. In this proposed work, the sender node sends the query packet to the entire relay node which is clearly mentioned in Figures 3(a) and 3(b).

After sending the query packet to all the nodes, each and every node updates the position and distance to the sink node. A node without acknowledgment is considered as void node, and it is clearly mentioned in Figure 3(b). After a certain period of time, the sink node starts to update each and every sensor node's position and distance via the shortest path to the source node. By introducing this methodology, the power consumption is highly minimized during the transmission of data packets Algorithm 1.

3.3.1. Distance Vector Establishment Algorithm. Clustered DVGOR protocol already knew the position of sensor nodes with an enhanced periodic beaconing algorithm. With the

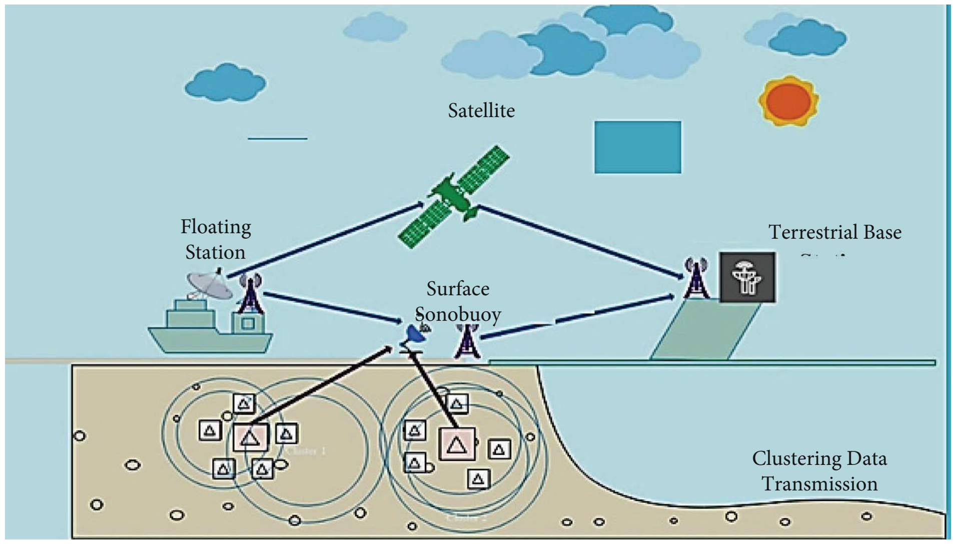
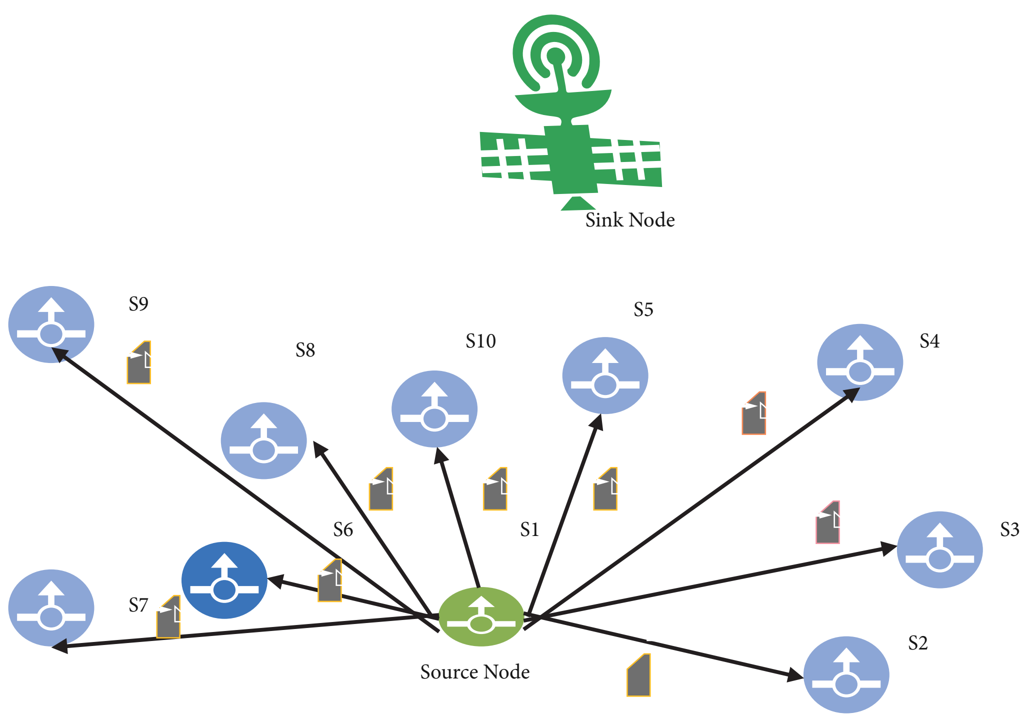
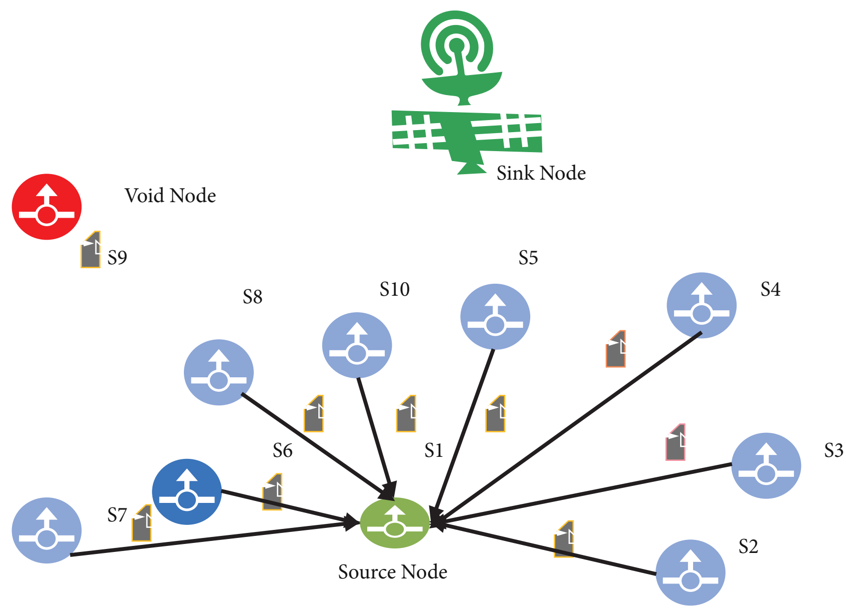


FIGURE 2: System model of proposed work.



(a)

FIGURE 3: Continued.



(b)

Figure 3: (a) Underwater sender node sends query packet to all the nodes. (b) Underwater sender node gets reply query packet from all the eligible nodes.

Procedure:
$e_{pB} \leftarrow$ Enhanced Periodic Beaconing message
If
QID Generates
Identify the location of all the sensor nodes **then**
Else
QID stop then
Stop Beaconing
end if
end else
end procedure

Algorithm 1: Enhanced periodic beaconing algorithm.

help of the beaconing, it creates a vector link and sends the data with minimal hop count. When compared to existing work, it is clearly mentioned that the distance vector establishment completely knows the void region. Here, a long detour problem is completely avoided with the help of the least hop count [23].

3.3.2. Creation of Distance Vector Establishment. Distance vectors are used to estimate the distances between nodes and facilitate routing decisions based on these estimations. Geo-opportunistic routing protocols rely on the knowledge of node positions to make forwarding decisions for creating the vector establishment. Distance vectors help in establishing the geographic positions of nodes within the network. Each node maintains a distance vector that contains information about the distances or geographical coordinates of other nodes in the network. Distance vectors enable the calculation of routing metrics, such as the distance or the estimated time it takes to reach a destination. These metrics are essential for making routing decisions based on geographical proximity. By comparing the distances or positions provided by the distance vectors, the routing protocol can determine the most suitable next hop or forwarding node for a packet. Geo-opportunistic routing protocols exploit opportunities for message delivery based on the proximity of nodes and their movements. Distance vectors provide an estimate of the distance or proximity between nodes, allowing the routing protocol to select forwarding nodes that are in close vicinity to the destination or have a higher chance of encountering the destination node in the future.

(1) The distance vector establishment determines the hop count using query ID

(2) In the entire sensor node, the packet with the larger query ID is considered to be a new query packet

(3) The query packet arrives at node *i*, where it is compared to the legitimate query ID

(4) The query packet is considered as newly generated if the size reaches the registered query ID and the sensor nodes automatically update the value, which is increased as $n_i + 1$

(5) When a query packet's size is less than the query ID that was previously recorded, it is regarded as a delay and the packets are placed in a queue to access shared channel media

(6) The query packet with the same-recorded query ID is considered as multiple copies, which are arrived at several times at the node

It has been worked under the waiting mechanism to realize the geo-opportunistic protocol to transmit the data among multiple relay candidates with one-hop or two-hop reachable distance which is clearly shown in Figures 4 and 5 to propagate the data to maximum transmission range Algorithm 2.

3.4. Cluster Head Election and Cluster Set Formation Algorithm. Normally, UWSN is a long-term monitoring process with very limited bandwidth, so it is more essential to limit the power during the data transmission. In this approach, all the nodes(s) compete to choose the optimum cluster because the cluster head is authorised to aggregate all the received data from the source node and forward the data to the next cluster head [24, 25]. The cluster head is authorised to aggregate all the received data from the source node, forward the data to the next cluster head, and enhance the lifespan of the sensor network to provide efficient energy. The clustered set formation algorithm has an initial random weight value. The weight represents the energy level or the importance of a node in the network. The sensor nodes transmit their weight information to their neighbours. Each node selects a subset of nodes with the highest weights as its cluster members. The number of cluster members is determined by a predefined parameter, whereas it aims to balance the energy consumption among the nodes in UWSNs. It provides an efficient way to collect and transmit data in an energy-efficient manner, considering the unique characteristics of underwater environments.

The following steps are to be followed for electing the best cluster head to forward the data from one cluster to another cluster:

(1) From all the qualified sensor nodes, the best cluster heads chosen based on residual energy

(2) The best cluster head will be located at a minimal distance from the sink node

(3) During transmission, a node with a higher residual energy is chosen to serve as the cluster head (CH)

(4) If the residual energy R_E is greater than the threshold value with the shortest distance (*d*), it will act as a cluster head and the node with lesser residual energy R_E will act as a normal node

To satisfy all these conditions, the source node starts to broadcast the data packets that depend on the distance from one cluster head to the elected cluster head [8, 26]. A cluster head with a minimal hop count gathers all the data packets from the source node, and the cluster formation is clearly mentioned in Figure 6. After gathering all the information, the CH transmits the data packets to the other minimal hop count cluster head. It is the advantage for enhancing the packet delivery ratio with minimal energy consumption.

3.5. Packet Delivery Estimation. In this section, the calculation of packet delivery ratio $P(a, b)$ to the number of bits (n) with distance (D) is used to forward the data packet in a greedy manner with a high SNR ratio [27]. Transmitting the data with the largest link over a long-distance communication is not possible in real time, whereas in the shortest link, the probability of receiving the data is not up to the level. Therefore, an average SNR ratio is needed to improve the performance of Algorithm 3.

The average SNR ratio over distance D is given as follows:

$$(\mathbf{D}) = \frac{\mathrm{Ea}}{\mathbf{b}}(\mathbf{a}, \mathbf{b})\mathbf{N_o}, \quad (3)$$

where E_a is the average energy per bit during transmission and N_o is the power.

3.6. Next-Hop Forwarder Set Algorithm. By using the next-hop forwarder set algorithm, one qualified cluster set acts as a next-hop forwarder which is shown in Figure 7. It selects only one neighbour cluster set to transmit the data to sink node [28, 29]. Once the transmission completion node goes to ideal condition and power consumption reduced when compared to existing work. If the acoustic link goes under disconnection, the packet may be lost. So, the selected cluster set must hear about the transmission to avoid the hidden terminal problem.

(1) It is important to choose the best cluster set with a minimal hop count to forward the data packets from one hop to the next-hop forwarder

(2) This process will further improve the packet delivery ratio with minimal energy consumption, and it helps to reduce the collision of data packets during data transmission

(3) At the end of the process, all the data packets are aggregated and move on to the next level

4. Simulated Results and Discussions

4.1. Simulation Setup. In this section, we evaluate the simulation and comparison of the proposed method vs. the existing method, and the results in the analysis under the performance of DVOR, modified DVGOR, and

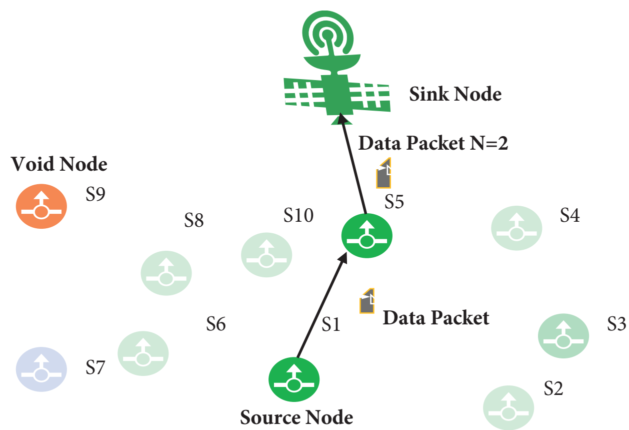


FIGURE 4: Sender node sends data packet to relay nodes using distance vector with $N = 1$.

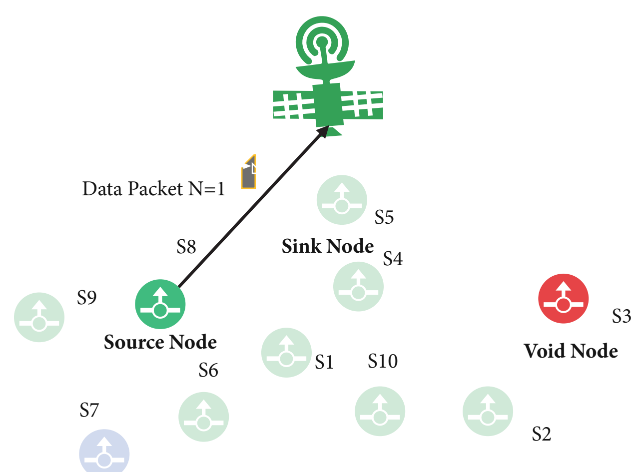


FIGURE 5: Sender node sends data packet to relay nodes using distance vector with $N = 2$.

If
Query ID greater than Recorded Query ID **then**
New query Packet $N_i = n_i + 1$
Increased as hop count Value as Infinity
Else if
Query ID less than Recorded Query ID **then**
Delay, Queuing
Else if
Query ID equal to Recorded Query ID **then**
Multiple copies of Duplicate data
End if
End else if
End else if
End procedure

ALGORITHM 2: Arriving query packet by using distance vector establishment.

clustered DVGOR are mentioned in Table 1. The proposed algorithm has been attained and evaluated the performance by using NS2 with the aqua simulator. AquaSim is to simulate the impairment of the acoustic channel. Generally, NS2 is used in a wide range of network technologies and protocols, including routing protocols and wireless communication. It is used to evaluate the performance of network protocols, study network

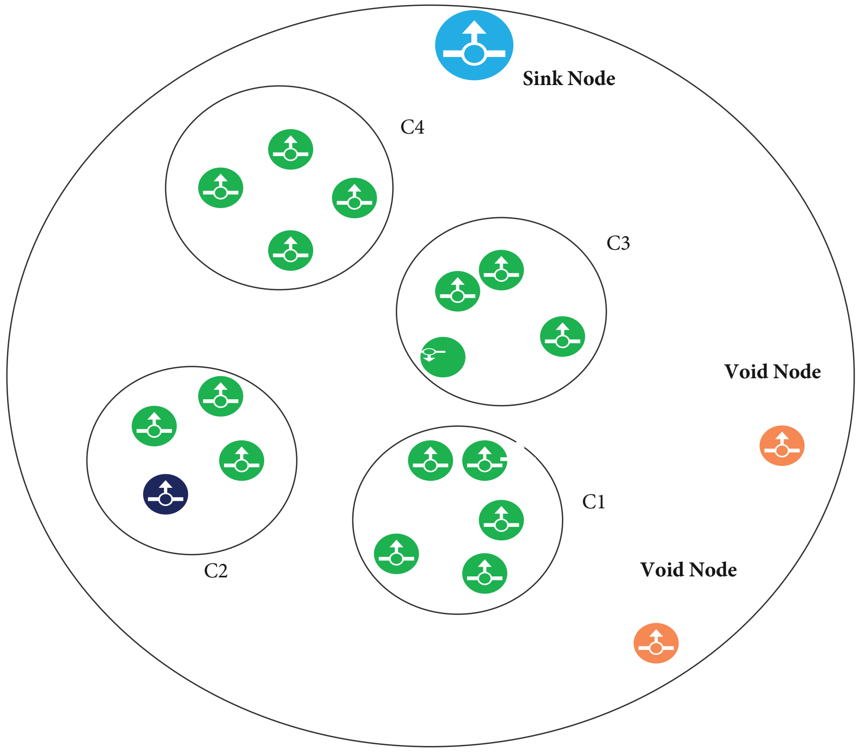


FIGURE 6: Clustering formation in UWSN.

Procedure: Procedure
$s \longrightarrow$ Sensor node
EcH $\longrightarrow$ Elected Clustered Head
ScH $\longrightarrow$ Selected Clustered Head
$R_{E(v)} \longrightarrow$ Residual Energy
$d \longrightarrow$ Distance
If
$R_{E(v)} > \text{TH}$ **then**
Select cluster head among all the sensor nodes **then**
Else
$R_{E(v)} < \text{TH}$ **then**
Consider as a normal node
end if
end if
end procedure

ALGORITHM 3: Cluster head selection and cluster set formation algorithm.

behavior under different conditions, and develop and test new networking algorithms. By simulating the underwater networking environment, it is specially designed. It is used for underwater monitoring and data collection applications which include models for underwater channel behavior, sound speed profiles, and other factors specific to the underwater environment which has unique characteristics and challenges due to the underwater environment. Hundred sensor nodes are randomly deployed in a three-dimensional manner over the entire area of 500 m × 500 m × 500 m. The maximum range of one-hop transmission is set as 250 m with a data rate of 10 kbps, and the data-packet size is 128 bytes. The initial energy of the source node and sink node is set as 10000 nJ and 400 nJ. On the water surface, 5 sonobuoys are deployed. These nodes broadcast the query packet periodically for each 20 s to particular selected sensor nodes within the communication range. The data packets contain headers and trailers. In the graph, the comparison of various parameters such as packet delivery ratio, end-to-end delay, average energy consumption, and throughput of various simulated parameters is plotted.

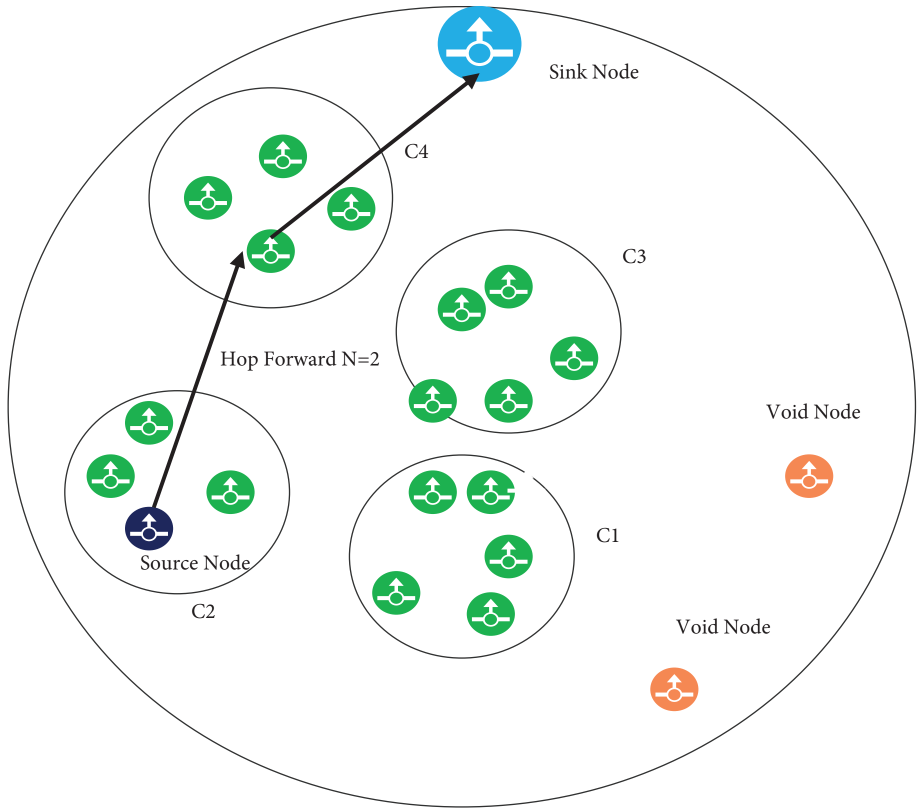


Figure 7: Transmitting clustering data from one cluster hop to another cluster hop in UWSN.

Table 1: Network parameters.

S. no.	Parameters	Description
1	Sensor nodes	50–500
2	Sonobuoys	05
3	Deployment region	1000 m × 1000 m
4	Node transmission range	250 m
5	Data rate	10 kbps
6	Data payload size	128 bytes
7	Node placement	Mobility
8	Routing protocol	Clustered geo-opportunistic routing protocol
9	Simulation time	1000 s
10	Cluster head	4
11	Cluster diameter	100 m

4.2. Performance Metrics. In wireless sensor network performance metrics such as QoS, optimization maintains the qualitative and quantitative measure of how the network should be reliable, and how many parameters are used to enhance the proposed work. In this contrast, some of the metrics are used to measure the output efficiency over the entire network. The proposed methodology is compared with DVGOR, CSSP, and EIIZR schemes. The EIIZR scheme implements both interzone and intrazone routing in the sensing field. The proposed CDVDOR protocol is employed to attain the clustering mechanism for reducing the average energy consumption and improving the network lifetime, coverage rate, and accuracy rate with network consistency. The performance results are simulated in NS3 along with aquasim that has been carried over by the Linux platform. It gives a different service flow methodology from real-time situation, and various effects occur inside the network. The simulation setup settings are mentioned in:

4.2.1. Analysis 1

(1) Network Lifetime vs. Number of Nodes. Network Lifetime refers to the duration for which the network can operate effectively without exhausting its energy source and various metrics are widely used to describe the network lifetime [30–32]. For determining the network lifetime associated with the UWSN, various metrics are used. But here, 50–500 sensor nodes are used to compare and evaluate the performance of the network. In this scenario, a Geographical

opportunistic routing protocol with a clustering mechanism (CDVGOR) has been implemented to compare and evaluate the network lifetime. During this time, the quality of network lifetime has been achieved because the clustered mechanism has more stability period in the network. During data transmission from 1st to 500th node, can be mutually communicate with each other and transmit hello packet to all the node, it determines the shortest path and also find out the void node throughout the entire network.

Scenario 1. Initially, in 1st round, 50 sensor nodes are involved, and it is introduced to transmit the data over the sink node whereas the network lifetime has been improved by 39.5%, and it is clearly viewed in Figure 8(a). The motivation behind the improved results in sensor nodes works under sleep/wake scheduling mechanism and waiting mechanism strategy attained the data routing and cluster selection across the entire network it has been maintained constant data routing.

Scenario 2. On 2nd round to 6th round, 100–500 number of sensor nodes are involved, and 10 nodes are considered as void node. While transmitting the data, lifetime of the network drastically improved with 79%, 63%, 57%, and 52% when compared to DVGOR, CSSP, and EIIZR. It occurs due to the CDVGOR transmits the data with high link quality along with an enhanced periodic beaconing algorithm whereas the 10% dead nodes or void nodes are identified. The comparison of the network lifetime in terms of DVGOR, CSSP, and EIIZR schemes is clearly mentioned in Figure 8(b), respectively. From Figure 8, it was observed that the lifetime of the network in CDVGOR is maintained over a long period with 100–500 number of sensor nodes. Therefore, CDGVOR clearly shows that the consistency of the network is maintained for a prolonged time among multiple clustering nodes which in turn leads to enlarging the network lifetime in UWSN.

4.2.2. Analysis 2

(1) Average Energy Consumption vs. Number of Nodes (AEC). The AEC [33, 34] can be determined by

$$\text{AEC} = \frac{\text{Total energy consumed by nodes}}{\text{Total nodes}}. \tag{4}$$

(2) Before Initialization. The AEC comparison of the entire network is described in Figure 8(a). As a result, increasing the number of sensor nodes will increase AEC because increasing the number of nodes and hops increases the amount of data that can be transmitted from source node to sink node. In this proposed scheme, an enhanced periodic beaconing algorithm is used in network topology. Before initializing the data transmission, the source node sends a query packet to all the nodes and finds out the shortest path along with the number of nodes present within the communication range. As stated in Figure 8(b), AEC in the entire network before initialization has achieved less ACE with 89% for underwater applications when compared to CSSP, EIIZR, and DVGOR schemes accordingly.

(3) After Initialization. After initializing the data transmission, all the data are aggregated and transmitted to CH. At that time, only a small amount of power was consumed due to less data aggregation in cluster topology which is depicted in Figure 9. So that it is observed that clustered DVGOR consumes less amount of energy with 20% for 100 nodes than all the existing protocols such as DVGOR, CSSP, and EIIZR schemes with 82%,76%, and 56%, respectively. Furthermore, sharing the information from sender to receiver undergoes the process of saving power or it will maintain the high residual energy with 30% efficiency (power saving mode) because the efficient sleep/wake scheduling mechanism is incorporated in the model and also network lifetime also increased gradually.

4.2.3. Analysis 3

(1) Statistical Analysis. Network consistency vs. number of nodes: The NC states the duration for which the network remains consistent in transmitting data packets before and after cluster formation without any alterations to the routing path. The assessment of network consistency (NC) serves as a crucial metric that directly influences the overall performance of the entire network. In this work, the NC has been measured as an average number of rounds taken before the first round change in the network Let “n” be the total number of clusters present in the network can be evaluated by

$$\text{NC} = \frac{\text{Number of nodes during first round}}{n}. \tag{5}$$

The NC of the proposed CDVGOR is better than CSSP, EIIZR, and DVGOR schemes which are shown in Figure 10. The rationale behind the NC enhancement is the appropriate selection of cluster head, and the optimal path selection for routing the data reduces the frequent change in the cluster for the entire network and also achieves the scalability in the clustering solution with number of cluster rounds. Besides, this circumstance also increases the consistent routing path and attains network consistency from one cluster head to another cluster head and CH to sink for a prolonged time period with 6 rounds. In spite of this, there is a regular change in data routing for CSSP, EIIZR, and DVGOR schemes; owing to the selection of an undefined path, meanwhile, inconsistent routing path also occurs in the network. According to the data presented in Figure 10, *the x*-axis represents the number of nodes, and *the y*-axis represents time. The proposed CDVGOR scheme exhibits superior network consistency with 80% when compared to existing schemes.

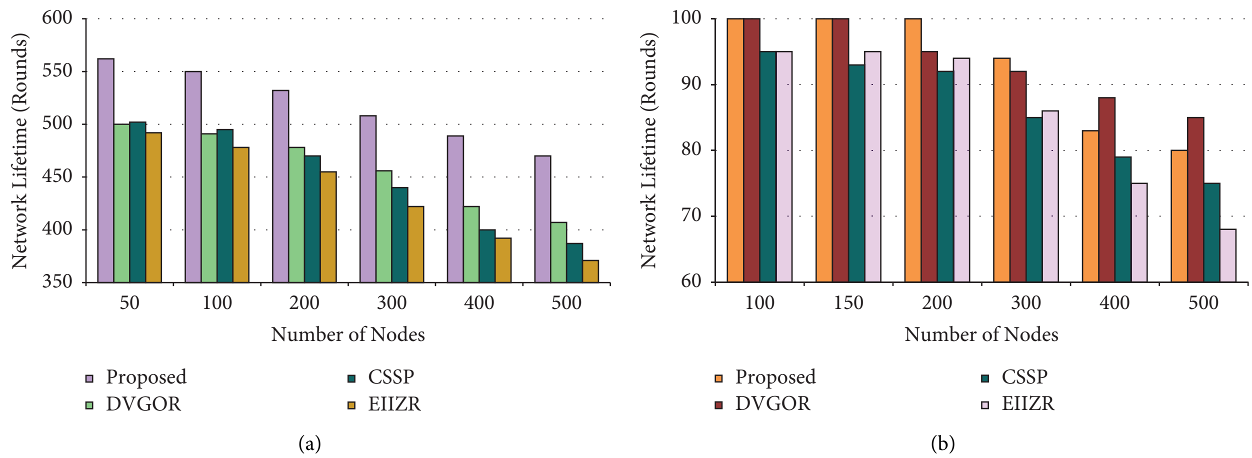


FIGURE 8: Comparison of NL: (a) scenerio 1 and (b) scenerio 2.

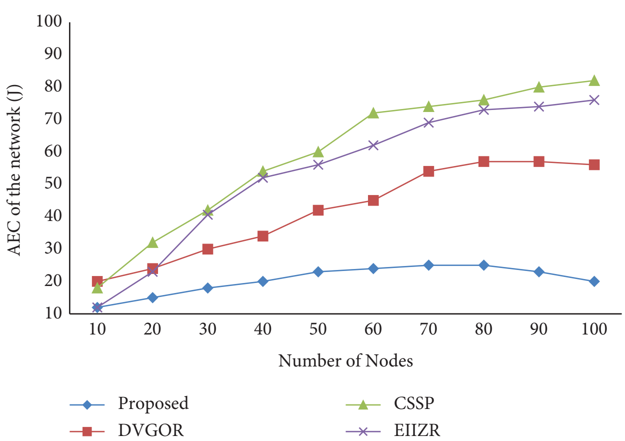


FIGURE 9: Comparison of AEC with various routing protocols.

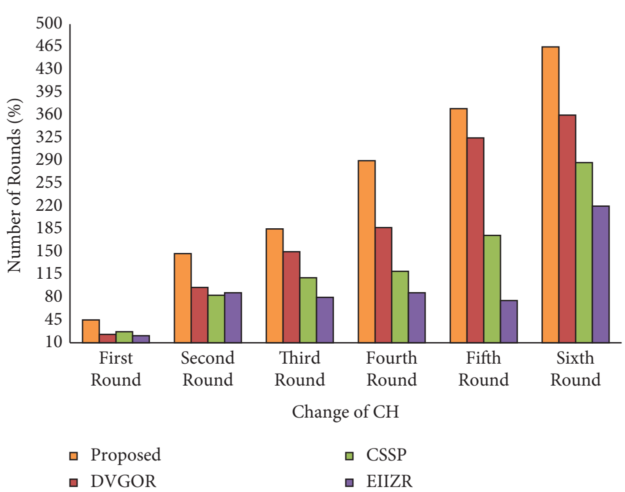


FIGURE 10: Statistical analysis for network consistency.

4.2.4. Analysis 4

(1) Number of Active Nodes vs. Coverage Rate. The number of active nodes and network coverage ratio (NCR) is determined by

$$(\%) = \frac{A_n}{C_{\max}}, \quad (6)$$

where A_n represents the total area covered by the deployed nodes determines the extent of network coverage and $C_{\max}$ denotes the deployed node's coverage extends to the maximum area possible.

The comparison of NCR (network coverage ratio) for various schemes is illustrated in Figure 11. The observation of the proposed scheme CDVGOR with 100 number of deployed nodes attains 89% better NCR than 64%, 60%, and 47% such as CSSP, EIIZR, and DVGOR schemes. The presented statistics indicate a linear improvement in the performance of the proposed CDVGOR scheme with an increase in the number of scattered nodes. Specifically, the proposed scheme remains 89% NCR for the 100 nodes environment and continues to persist over existing schemes. These results are attributed to the identification of an optimal fitness function within the CDVGOR, contributing to its successful performance. The heterogeneous fault detection process also includes comprehensive analyses of hardware, software, and time-based faults. By employing this strategy, network partitioning issues are reduced across the entire network. Furthermore, the sustained coverage in CDVGOR contributes to achieving the maximum NCR and improving the packet delivery ratio in UWSN. On the contrary, the presence of unreliable connectivity in the sensing region leads to frequent network partitioning issues in existing schemes. The proposed work successfully tackled the challenge of intentional classification in situations with higher fault probabilities.

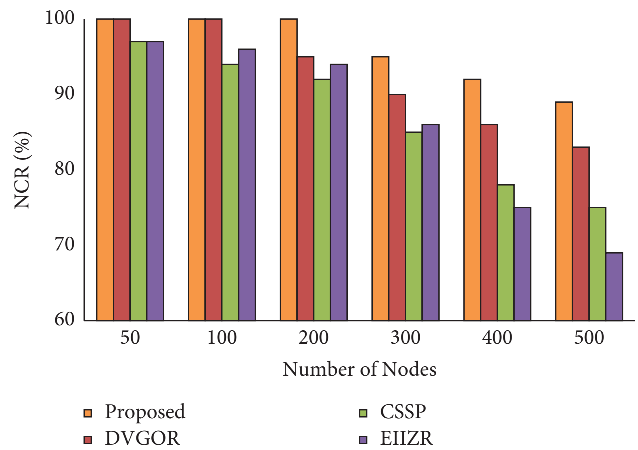


Figure 11: Comparison of NCR for various routing protocols.

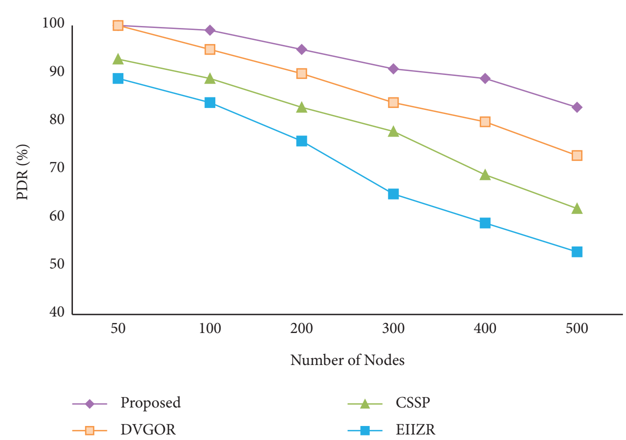


Figure 12: Comparison of PDR for various routing protocols.

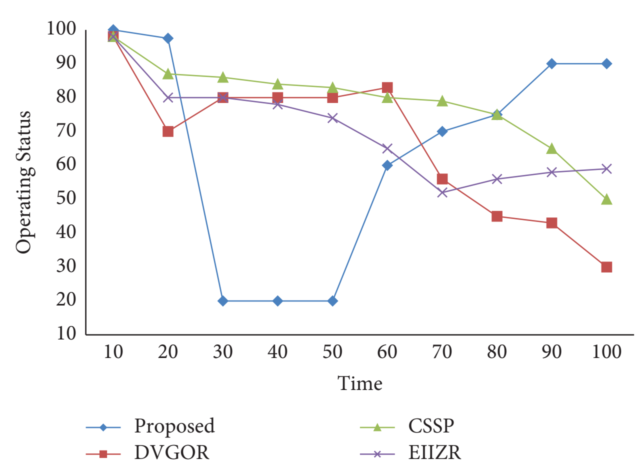


Figure 13: Comparison of NSR for Various routing Protocols.

4.2.5. Analysis 5

(1) Packet Delivery Ratio vs. Number of Nodes. The packet delivery ratio is defined as the total number of packets that arrived at the sink node, which is generated by the sensor nodes. The PDR is the most important parameter for better performance. The result of the packet delivery ratio differs in different nodes and different protocols, which is shown in Figure 12. It is clearly assured that the CSSP is 50%, EIIZR is 59%, and DVOR is 62% which gives a very low packet

Table 2: Performance metrics comparison of the proposed model over existing methods.

Performance metrics	Clustered DVGOR (proposed)	DVGOR	CSSP	EIIZR
Network lifetime (rounds)	79%	54%	63%	59%
AEC (J)	20 nJ	56 nJ	76 nJ	82 nJ
Network consistency	79	54	63	59
PDR (%)	85	63	59	50

delivery ratio when compared to the proposed CDVGOR which is 89%. If the packet size or packet ratio varies based on different applications, it may consume less power for transmitting the data to the end user. However, in a real-time application, it assures that the probability of packet delivery ratio efficiently gives an improved efficiency than all the existing routing protocols.

(2) Impact of Network Stability Rate. The performance metric evaluated the NSR by considering its operational status and estimating the time it takes for detection. The operating status encompasses two different statuses such as query packet sending mechanism and data packet transmission mechanism whereas the operating status implies that the network functions consistently without any nodes being damaged. At the same time, the void node updates the hop count as infinity *abd* it is calculated by

$$Sn = T_d - Tf, \quad (7)$$

where T_d represents the time at which the damaged node is detected and Tf intends the time at the damaged node appears. Normally, the scheme has lesser DT that provides higher NSR in UWSN. From Figure 13, it is noticed that the proposed CDGVOR scheme has a higher NSR than CSSP, EIIZR, and DVGOR schemes. Considering the one scenario from the 30th node to the 50th node, it maintains a constant stability rate of 20 s. The reason behind the constant rate and time indicates that the sleep-wake mechanism has been implemented. While transmitting the data if there is no data packet transmitted through the entire network, it automatically goes off condition for maintaining residual energy. The statistical results validate that the proposed CDVGOR can effectively sustain the network over a prolonged period. This accomplishment stems from the integration of a distributed heterogeneous sensor fault model in the scheme, which ensures a fault-free environment during data routing.

Table 2 indicates the performance metrics comprehensive analysis of the proposed model over existing methods.

5. Conclusion

A new CDVGOR has been achieved effectively with the proposed clustering-based routing algorithm. More specifically, this article shows how to transmit the data with the shortest path and least hop count to improve the performance metrics such as packet delivery ratio, end-to-end delay, power consumption, and throughput with different values and sizes. When compared to existing methodologies, the proposed methodology shows the best choice for any practical application at present. In the near future, it is envisioned that the simulated results will provide some insight into the design of an energy-efficient routing strategy for underwater wireless acoustic sensor networks. The future scope of the work is to improve the security based on distance vector-based geo-opportunistic routing protocol with a clustering mechanism, and it needs to recover the void nodes using recovery node algorithms in UWSN.

5.1. Future Work. To transmit the data from sender to receiver, ambient noise may be introduced inside the unit, and at the same time, there may be a high probability of introducing security issues in the network. To control the issues, an enhanced security-controlled algorithm needs to be implemented across the network, and at the same time, automation implementation may be implemented by using IoT sensor nodes.

Data Availability

The data used to support the findings of this study are included within the article.

Disclosure

It was performed as a part of the Employment of Ragavi B, Dr. N.G.P. Institute of Technology, Coimbatore-48, India.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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