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RESEARCH ARTICLE

Dolphin Swarm Inspired Protocol (DSIP) for Routing in Underwater Wireless Sensor Networks

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Abstract – Underwater communication is still carried out using communication cables because of the minimum development that is established in underwater wireless communications. The utilization of wires to make sure the connectivity of sensor nodes that are located at the bottom of the sea is highly expensive. Finding the best route to send the sensed data to the destination in minimum duration has become a primary challenge in underwater wireless sensor networks (UWSN). Feasible routing protocols available for general sensor networks are not feasible for UWSN because of the difficult communication medium. Existing routing protocol face the problem of consuming more energy to deliver the data packet and also due to selecting the unfit route it faces more delay. To overcome the routing challenges present in UWSN, Dolphin Swarm Inspired Protocol (DSIP) is proposed in this paper. DSIP is inspired by the swarming nature of dolphins towards finding their food. Four significant phases involved in DSIP to find the best route in UWSN are searching, calling, reception, and predation. NS3 is used to evaluate the performance of DSIP against previous routing protocols with benchmark metrics namely packet delivery ratio, end-to-end delay, node death rate, and energy consumption. Results indicate that DSIP has consumed 1.43 times less energy than other previous protocols.

Index Terms – Energy, Delay, Swarm, Dolphin, Routing, Packet Delivery Ratio.

1. INTRODUCTION

In recent years, researchers started their focus on finding solutions for the problems that arise in sensor networks. Specifically, Underwater Wireless Sensor Network (UWSN) got attracted more because of its wide applicability in military fields, ocean surveillance, disaster forecasting cum detecting, and military defense [1]. Acoustic based communications are trusted as the best strategy for long-distance communication because of their attenuation radio characteristics underwater. Initially, minimum propagation speed ends with enhanced end-to-end delay. By default, the acoustic signal's propagation speed is expected to be 1500 m/s [2]. An important aspect of the acoustic signal is its propagation speed because it gets weaken due to water temperature, depth, and specifically salinity. Such type of delay leads to a big challenge in scheduling the transmission of the packet, network synchronization, and find the best route to the destination. Secondly, the channels present underwater have the characteristic of high-level multipath fading with Doppler spread, constrained spectrum resource, and uncertainty in the spatial area [3, 4]. These characters make UWSN face increased routing error which results in losing the reliability of routing. In oceans, UWSN and Sonar systems alone are not present, but natural acoustic systems are also present (i.e., marine mammals). These natural and artificial sensor systems have/share common water area networking. These kinds of systems make use of utilizing acoustic signals for sensing, detecting, navigating, and communicating. Unexpectedly, acoustic signals are dependent on the frequency which will range from 10 hertz to 100-kilo hertz [5, 6].

UWSN faced multiple conditions like increased propagation delay, limited bandwidth and battery life.

Radio waves are entirely unfeasible in underwater communication where acoustic signal are used. Most underwater communication is geographic and it becomes hectic to main the route from source to destination. It faces more delay when the network size is increased. Delay acts as a route cause for network failure. Hence, it becomes necessary for a routing protocol to maintain one or two hops communication and finally integrating the same.

The development of artificial intelligence-enabled algorithms (i.e., bio-inspired algorithms) plays a major role in the routing protocol. Researchers started using bio-inspired concepts to design the routing protocol to meet high performance in terms of delay, throughput, packet delivery ratio, and energy consumption [7, 8]. Bio-inspired concepts based routing protocols attains increased performance when comparing with traditional routing protocols. Also, this kind of routing

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protocol can be applied in a terrestrial environment like UWSN.

1.1. Problem Statement

Radio based communications never suit for underwater communication where they require substitute as acoustic-based communications. This replacement makes the speed of propagation 5 or 6times less than radio frequency which makes communication interchange from speed-of-light to speed-of-sound. Underwater applications like rescue missions, detection, etc are ad hoc by default and require deployment in minimum time without any planning [9,10]. During such situations, routing protocol needs to identify the location of a node without having any prior knowledge about the network. Critical routing protocols consume more energy and reduce the network lifetime. Protocols that are available for available for common sensor networks or other rapid networks will never suit for UWSN.

1.2. Objectives

Primary intention of this research paper is to develop a swarm-based protocol for routing in UWSN to address the scalability and energy consumption issues which is a mandatory requirement in the network.

This paper proposes a bio-inspired-based routing protocol that is inspired by natural swarming characteristics of dolphins namely Dolphin Swarm Inspired Protocol (DSIP) which aims to meet the primary objective of finding a better route to destination and attempt to find an alternate route during failure.

Current section has discussed about UWSN, problems faced in UWSN routing protocols and ended with problem statement and objective of the research work. Succeeding section related literatures of the problem are reviewed. Section 3 presents the proposed novel protocol Dolphin Swarm Inspired Protocol for routing in UWSN. Simulation setting and performance metrics used for evaluation of the proposed protocol are presented in Section 4. Discussions of results obtained against the previous protocols are provided in Section 5. Conclusions with future research dimension of the current research are discussed in Section 6.

2. LITERATURE REVIEW

Scalable asynchronous localization algorithm [4] is proposed for predicting the mobility of nodes. Tidal mobility model is built to estimate the location of nodes. Routing is performed based on updated location of mobile sensor nodes in underwater networks. Contention Window Adjustment Backoff Algorithm [6] proposed reinforcement learning based methodology to adapt and make adjustment with the sliding window by learning the network communication in an automatic manner.

Energy-Efficient Depth Based on Probabilistic Routing [11] is designed to enhance the rate of reliable data transfer in UWSN than traditional depth-based routing. It considers nodes' depth, forwarding number, and balance energy. Increased delay in delivering the packet leads a way to network failure. Energy-Efficient Chain Based Routing Protocol [12] proposed by considering complex features of UWSN. IT makes communication-based on a distance between nodes which will be utilized for domain monitoring during dynamic state and it expects location free hop by hop communication. The reliability of the nodes is calculated to choose the optimum relay nodes. Asymmetric Link-Based Reverse Routing [13] is proposed to seek the preeminent route to the destination from source to enable bidirectional communication. Nodes are designed to maintain a table to analyze the state of the link. Prioritization is applied to utilizing the symmetric links. Three-hop routing is established for searching the route in a reverse manner. Void nodes are eliminated to enable smooth routing. Event-Driven Energy-Depth and Channel-Aware Routing [14] is proposed for monitoring the ocean environment and intrusion detection. The Head of the cluster initiates the routing process by utilizing the mobile agent. The multipath strategy is applied to increase the reliability and connectivity of routing. A traversal algorithm is presented to reorienting the direction.

Enhanced Interpretation for Underwater Localization [15] is proposed to meet the meet for deploying the sensor nodes in underwater communication. The global positioning system concept was used to gather the location of nodes but it didn't propagate in an underwater network. The clustering concept is adopted to receive all sensed information and the sink node attempts to send the received and gathered data to further processing. Level-Based Adaptive Geo-Routing [16] is proposed to decrease energy consumption in UWSN. It performs the joint forwarding factor at each node by using the residual energy. Determination of nest best hop is calculated before perfuming the routing process.

Energy Efficient Multi-Objective Evolutionary Routing [17] proposed to explore the features of the genetic algorithm. It mainly aims to give reliability to the route that it determines. Information related to energy consumption in routes is gathered from neighbor nodes. Diagonal and Vertical Routing Protocol [18] is proposed to minimize the delay in UWSN. Communications are done based on a flooding scheme where the messages pass between sending node to surface node. It makes a local decision to forward data packets under the flooding scheme.

Transport Layer Protocol [19] is proposed to avoid retransmission in UWSN. The network latency concept is modified to meet the need in UWSN. By adopting the retransmission timeout the sensed data by nodes are made to reach the receiver node. However, the delay in receiving the

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data got increased and network congestion got decreased. Geographic Multipath Routing based on Geospatial Division [20] is proposed to make collaborate with current sensor nodes with neighbor nodes for transmitting the data. It aims to choose the next neighbor node in a cubic area. It attempts to find a route to a destination in three-dimension topology. Stochastic Modeling of Depth Based Routing [21] is proposed to numerically derive the significance of different performance metrics of UWSN. It focuses on node deployment and its mobility to avoid data loss. Routing protocols have been made to play a pivotal role to determine the efficiency of routing. AUV-aided Efficient Data Gathering Routing Protocol [22] is proposed to delivering the data to the destination in a reliable manner. To enhance the network lifetime it collects data from underwater network gateways. The shortest-path tree methodology is applied to find the short cum best route between the gateway node and the destination node.

Geography-based Opportunistic Routing [23] aimed to increase the packet delivery to destination and eliminate the void problem that arises in the network. An optimum forwarding strategy is applied to choose the preeminent neighbor node for transmission. Failure of handling communication creates void messages to assist other nodes in utilizing the error route. Region-Based Cooperative Routing [24] is proposed to enhance the forwarding of the strategy over Rayleigh-fading-channels. The data sender node is expected to send the signal (i.e., sensed) to the receiver node and this is performed to minimize the bit error rate. Acknowledgment based communication is maintained to ensure the quality of service. Delay Sensitive Routing [25] proposed to enhance the depth-based routing efficiency. It minimizes the delay using optimum weight function. It assists in minimizing data loss and increases signal strength and increases data forwarding. A forwarding selection strategy is applied to minimize transmission. Different bio-inspired routing protocols [26, 27] are proposed for the different wireless ad-hoc network, but those protocols have poor performance while it is applied in UWSN. Merits and Demerits of Related Works are summarized in Table 1.

Related Works	Merits	Demerits
Scalable asynchronous localization algorithm [5]	It achieves precise localization with asynchronous clock of mobility enabled nodes in large scale UWSN	Ordinary nodes wait for a long time until the completion of localization tasks.
Contention Window Adjustment Backoff Algorithm [6]	It reduces the number of collisions and channel utilizations by adaptively changing the CW fixed contention window.	Reduced hop-count and increased delay to find out the active nodes.
Energy-Efficient Depth Based on Probabilistic Routing [11]	Reduced energy consumption towards finding optimum route.	Looping in route.
Energy-Efficient Chain Based Routing Protocol [12]	Increased reliability in finding the route to destination.	Increased time duration to maintain the load of nodes.
Asymmetric Link-Based Reverse Routing [13]	Bidirectional data communication.	Difficulty in adjusting the dynamic paths with the previous routing paths.
Event-Driven Energy-Depth and Channel-Aware Routing [14]	Flexibility cum customized services in finding route to destination.	Faces delay when network is scaled.
Enhanced Interpretation for Underwater Localization [15]	Reduced error in finding route to destination.	Low level synchronization of found route with neighbor nodes.
Level-Based Adaptive Geo-Routing [16]	It determines the best-next hop concerning a particular group of nodes.	Faces delay to find the energy available in the group of nodes.
Energy Efficient Multi-Objective Evolutionary Routing [17]	Unbalanced load among nodes.	Increased data packet loss.
Diagonal and Vertical Routing Protocol [18]	Flooding zone angle gives better performance in minimizing delay, optimum energy consumption and increased delivery ratio of packets.	Sensor nodes face difficulty to take the decision to data packets forwarding scheme in constrained flooding angle.

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Transport Layer Protocol [19]	Optimal RTO timer increases the data delivery rate and reduces the propagation delay.	Long propagation delay.
Geographic Multipath Routing based on Geospatial Division [20]	Flexible to find the best route paths & reduces the energy consumption for finding the route.	Decreases the network lifetime.
Stochastic Modeling of Depth Based Routing [21]	Increased delivery probability.	High transmission loss.
AUV-aided Efficient Data Gathering Routing Protocol [22]	Increases network throughput and minimizes energy consumption.	Difficult to find the sensor nodes if the nodes are not associated.
Geography-based Opportunistic Routing [23]	It improves the overall network performance in depth of the ocean and dense networks.	Failure in communication during convex void handling.
Region-Based Cooperative Routing [24]	It performs best in throughput, network lifetime and probability.	Increased delay to finding the available relay nodes.
Delay Sensitive Routing [25]	Reduced delay in delivering the data packets to destination.	Low level throughput
Different bio-inspired routing protocols [26, 27]	Reduced delay.	Increased energy consumption to deliver the data packets.

Table 1 Merits and Demerits of Related Works

3. DOLPHIN SWARM INSPIRED PROTOCOL

DSIP is developed based on the natural characteristics of dolphin. Since, swarm intelligence is the core concept of DSIP, it require dolphins with a threshold number which will assist in simulating the natural characters cum living habits of dolphin. In the process of optimization, every dolphin indicates a feasible solution and its expression gets varied based on the optimization problem. Equation. (1) defines the dolphins in DSIP and it helps to make a good understanding with D dimensions.

$$Dlph_j = [y_1, y_2, y_3, \dots, y_D] \ where\ j = (1,2,3, \dots, M) \quad (1)$$

Where M represents the count of dolphins, y_j act as a component for optimizing each dimension.

Individual-Optimum-Solution (IOS) and Neighborhood-Optimum-Solution (NOS) are two different variables that are linked with dolphin. For every $Dlph_j$ ($j = 1,2,3, \dots, M$), there exist two equivalent variables and it is described IOS_j ($j = 1,2,3, \dots, M$) and NOS_j ($j = 1,2,3, \dots, M$). IOS_jdenotes the optimum solution that is found in a single attempt by $Dlph_j$, and NOS_j denotes the optimum solution received from others or by itself.

Fitness $FTNS$ acts as a tool to judge whether the identified solution is good. In DSIP, FTNS is computed using a fitness function and the value closer to zero indicates the better fitness. Specific reason for this is, optimization performed at different research problems is entirely different. In DSIP, fitness function is denoted as $Fitness(Y)$.

DSIP involves three different types of distances that are to be used in sum, which are formulated in Equation. (2) to Equation. (4)

(a). Distance between $Dlph_j$ and $Dlph_k$ is mathematically described as:

$$Dlph_{j,k} = \left\| Dlph_j - Dlph_k \right\| \quad j,k = 1,2,3, \dots, M, \quad j \neq k \quad (2)$$

(b). Distance between $Dlph_j$ and NOS_j is mathematically described as:

$$DlphNOS_j = \left\| Dlph_j - NOS_j \right\|, \quad j = 1,2,3, \dots, M, \quad (3)$$

(c). Distance between NOS_j and NOS_k is mathematically described as:

$$DlphIOSNOS_j = \left\| IOS_j - NOS_j \right\|, \quad j = 1,2,3, \dots, M, \quad (4)$$

$Dlph_{j,k}$ Reduces the rate of information that is transferred between $Dlph_j$ and $Dlph_k$; $DlphNOS_j$ and $DlphIOSNOS_j$ assist the movement of $Dlph_j$ in the phase of predation.

DSIP involves 6 different phases namely (a) initialization, (b) searching, (c) calling, (d) reception (e) predation, and (f) termination. In initialization phase, random numbers of dolphins are generated in the simulation. Termination phase is

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fulfilled when it reaches the threshold number of iterations. Remaining phases of DSIP is discussed in the below sections.

3.1. Searching Phase

In this phase, every dolphin seeks for food in its local area by making different sounds in P random directions and the sound produced by dolphin is mathematically expressed in Equation. (5).

$$RD_j = [rd_1, rd_2, rd_3, \ldots, rd_D] \quad where\ (j = 1,2,3, \ldots P) \qquad (5)$$

Where P indicates count of sounds and rd_j represents the components present in individual dimension i.e., sound attribute. Equation. (6) formulates the sound.

$$\|RD_j\| = speed \quad where\ j = 1,2,3, \ldots, P \qquad (6)$$

Where speed is a static value that represent the speed in the sound travels. To avoid dolphins stuck with searching, DSIP sets a time limit Tm_1 i.e., before the end of time limit Tm_1, the sound RD_j produced at time t need to find a solution Y_{jkt} and it is mathematically expressed as Equation. (7).

$$Y_{jkt} = Dlph_j + RD_j t \qquad (7)$$

Equation. (8) Provides the fitness present in Equation. (7).

$$FTNS_{jkt} = Fitness(Y_{jkt}) \qquad (8)$$

If Equation. (9) gets true then NOS_j will be replaced by IOS_j, else NOS_j will never change.

$$FTNS(IOS_j) < FTNS(NOS_j) \qquad (9)$$

Once after all $Dlph_j$ update their IOS_j and NOS_j, DSIP enters next stage i.e., calling.

3.2. Calling Phase

In this current phase, every dolphin makes different sound to intimate the results of searching phase to other dolphins where it contains better solution with its location. The matrix related to the time of transmission is updated as below [28]:

For NOS_j, NOS_k, and TT_{jk}, if

$$Fitness(NOS_j) > Fitness(NOS_k) \qquad (10)$$

and

$$TT_{j,k} > \left[\frac{Dlph_{jk}}{B.speed}\right] \qquad (11)$$

3.3. Reception Phase

In DSIP, process of exchanging the information is maintained in $M \times M$ order matrix and it named as "time of transmission matrix" (TT), where TT_{jk} indicates the time taken by the sound to reach $Dlph_k$from $Dlph_j$(Wu et al., 2016). While DSIP entering the reception phaseTT_{jk} is minimized by '1' to mention that one-unit of time got over. Then DSIP verifies each term in TT_{jk} and if it is equivalent to '0' then it is assumed that the sound sent from $Dlph_k$ has reached$Dlph_j$. After that, DSIP replaces TT_{jk} with a new timeTT_2. Comparison is made between NOS_j and NOS_k as in Equation. (10).

3.4. Predation Phase

In this phase, every dolphin performs the calculation towards encircling radius Rad_2 and it indicates the distance present between dolphin optimum solution and its current position. It will assist to find a better new position. Information gathered by dolphin holds its current position, radius of searchingRad_1, IOS, NOS, and the two distances $DlphNOS$ and $DlphIOSNOS$. Rad_1Indicates the highest range in searching and it calculated by using Equation. (13).

$$Rad_1 = TT_1 \times speed \qquad (13)$$

Pseudocode of DSIP is presented in Algorithm 1 and Figure 1 shows the framework of DSIP.

Algorithm 1 provides the pseudocode of the proposed routing protocol DSIP. It begins with initialization of nodes and it performs fitness calculation for each node for sending the data. After setting the iteration count, process of finding the best route begins and it involves 4 phases namely Searching, Calling, Reception and Predation Phase. The process gets terminate when the iteration count reaches the maximum value.

Step 1: Initialization of randomly generated dolphins in $Dlph$in D-dimensions

Step 2: Perform the calculation of fitness for every individual dolphin $FTNS$

Step 3: Set threshold value for iteration

Step 4: Begin the iteration

Step 4.1: Searching Phase

$Y_{jkt} = FTNS\ (Dlph_j + RD_j t)$

$FTNS = \{\min(Y_{1kt}), \min(Y_{2kt}), \min(Y_{3kt}), \ldots, \min(Y_{Nkt})\}$

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$$FTNS_{Ki} = \begin{cases} FTNS(IOS_j) & if\ FTNS(IOS_j) < FTNS(NOS_j) \\ FTNS(NOS_j) & else \end{cases}$$

Step 4.2: Calling Phase

$$TT_{j,k} = \begin{cases} \left[\frac{Dlph_{jk}}{B.speed}\right] & if\ Fitness(NOS_j) > Fitness(NOS_k)\ and\ TT_{j,k} > \left[\frac{Dlph_{jk}}{B.speed}\right] \\ TT_{j,k} & else \end{cases}$$

Step 4.3: Reception Phase

$$FTNS_{Ki} = \begin{cases} FTNS(IOS_j) & if\ TT_{j,k} = 0\ and\ FTNS(IOS_j) < FTNS(NOS_j) \\ FTNS(NOS_j) & else \end{cases}$$

Step 4.4: Predation Phase

Find better position using $Rad_1 = TT_1 \times speed$

Step 5: Check iteration count, if it reached maximum then go to Step 6, else go to Step 4.1

Step 6: End

Algorithm 1 DSIP for Routing in UWSN

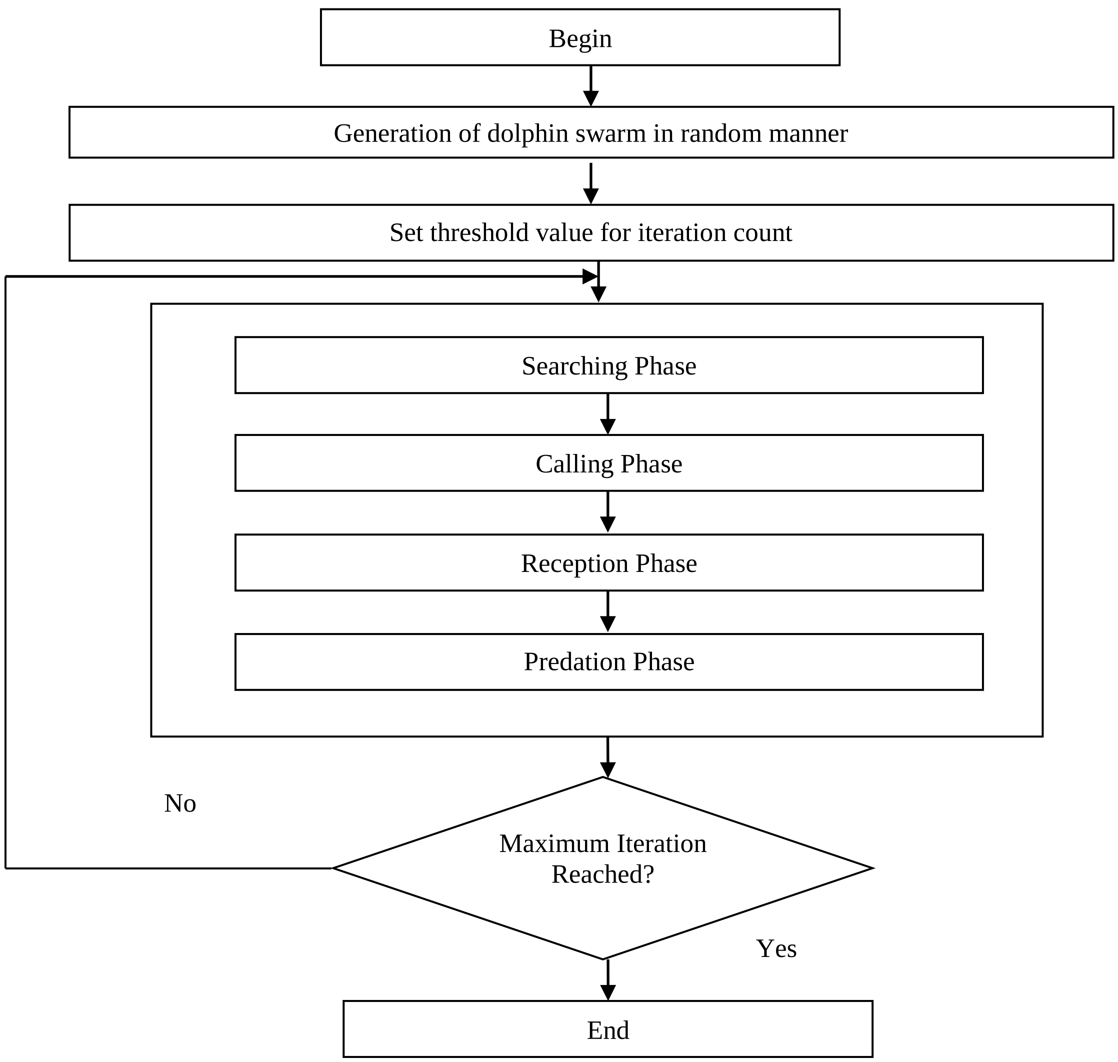

Figure 1 Framework of DSIP

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4. SIMULATION SETTINGS

4.1. Simulation

Performance of the protocol can be analyzed using different parameter like network size, link failure, pause time, malicious nodes etc. This research work has chosen the parameter Network-Size (i.e., No. of Nodes). To perform the simulation experiment, 250 nodes are deployed in a 3D monitoring space randomly. The width of the layer is set as 400m and the radius of communication is 500m. The pressure of acoustics is dependent on the relationship with transmission distance. Table 2 provides the detailed parameter setting used to evaluate DSIP against previous routing protocols namely EAVARP [29] and E-PULRP [30].

Parameters	Values
Underwater speed of sound	2000m/s
Idle state	168mW
Power of Transmit	60W
Bandwidth	100Hz
Boundary of Network	1.5kmx1.5kmx1.5km
MAC Protocol	CW-MAC802.11DCF
Layer width	≤150m
Runtime	1500s
Size of Packet	74bytes
Packet header size	20bytes
Each node of initial energy	450J
Transmission radius of sensor nodes	≈350m
Data transmission rate	20kbps
Number of nodes	101000
Number of sinks	≥4
Acoustic pressure of layer	110 dB(μPa)
Acoustic pressure of data transmission	113 dB(μPa)

Table 2. Simulation Settings

4.2. Performance Metrics

- Packet Delivery Ratio (PDR): It represents the overall energy consumed by all packets in UWSN.

$$PDR = \frac{Overall\ packets\ received\ by\ all\ destination\ node}{Overall\ packets\ sent\ by\ all\ source\ nodes} \quad (14)$$

- End-To-End Delay (ETED): It represents the overall time taken by all packets from starting of transmission till it reaches the sink node.

$$ETED = time\ of\ packet\ sent - time\ of\ packet\ received \quad (15)$$

- Node Death Rate: The ratio of sensor nodes that are exhausted from energy against the total number of sensor nodes. i.e., when the node battery level crosses 1% (i.e., threshold value), then that node is considered as dead node.

- Average Energy Consumption (AEC): It indicates the ratio of successful receiving data packets in the sink node against overall data packets transferred from all sensor nodes.

$$AEC = \left(\sum_{j=1}^{g} EC\right)/g \quad (16)$$

Where EC indicates the energy consumption and g indicates the hop count.

5. RESULTS AND DISCUSSIONS

5.1. Energy Consumption Analysis

Figure 2 demonstrates the relationship of DSIP with several nodes and energy consumption. By default, when the count of nodes increases, energy consumption also increases. E-PULRP and EAVARP have consumed more energy than DSIP. Swarming nature adapting in DSIP makes achieving minimum energy consumption. The specific reason for the enhanced consumption of energy by E-PULRP and EAVARP is broadcasting the probe packet to detect the relay node before it sends the data packet. DSIP applies the natural character of dolphins to find the best node that result in zero flooding and reduced energy consumption. Respective values of Figure.2 are provided in Table 3.

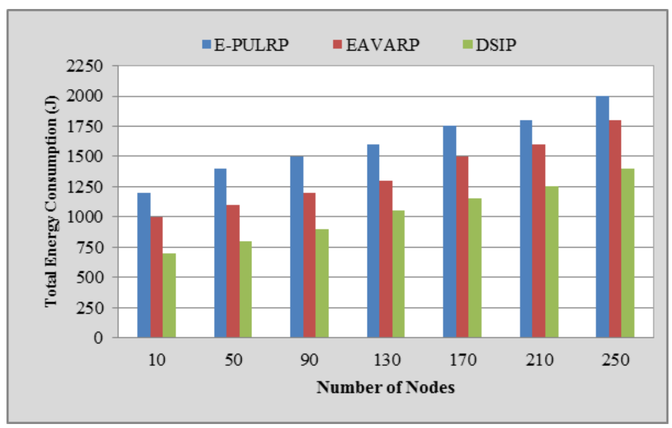

Figure 2 DSIP Vs Energy Consumption

No. of nodes	E-PULRP	EAVARP	DSIP
10	1200	1000	700
50	1400	1100	800
90	1500	1200	900
130	1600	1300	1050
170	1750	1500	1150
210	1800	1600	1250
250	2000	1800	1400

Table 3 Energy Consumption

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5.2. Delay Analysis

Figure 3 demonstrates the relationship of DSIP with several nodes and end-to-end delay. E-PULRP and EAVARP have faced more delays than DSIP. Also, DSIP sends data packets directly to reliable nodes via its calling-phase which results in greatly reduced end-to-end delay. Another specific reason for the greatly reduced end-to-end delay is DSIP avoids loop path. The important reason for high delay in E-PULRP and EAVARP is sending the probe packets repeatedly. Respective values of Figure 3 is provided in Table 4.

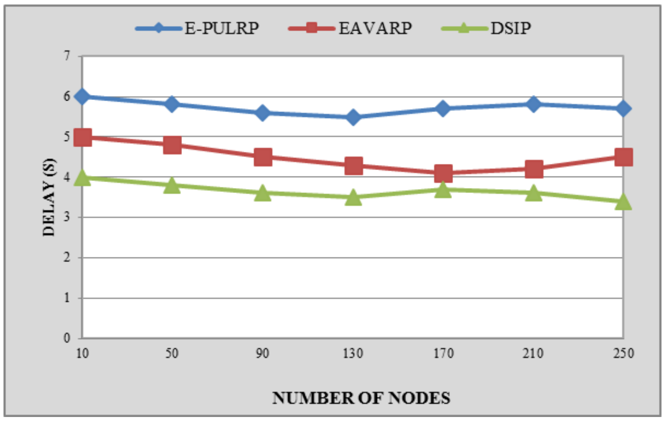

Figure 3 DSIP Vs Delay

No. of nodes	E-PULRP	EAVARP	DSIP
10	6	5	4
50	5.8	4.8	3.8
90	5.6	4.5	3.6
130	5.5	4.3	3.5
170	5.7	4.1	3.7
210	5.8	4.2	3.6
250	5.7	4.5	3.4

Table 4 Delay

5.3. Node Death Rate Analysis

Figure 4 demonstrates the relationship of DSIP with simulation time and death rate of sensor nodes. When there is an increase in simulation time, it is evident that the death rate of the sensor node gets increased in all protocols. In general, E-PULRP and EAVARP do not depend on relay nodes before they send data packets. Due to this, their energy consumption is rapidly getting increased. Further, the packet collision also enhances the energy consumption in E-PULRP and EAVARP. These reasons give a way to massive energy consumption and an increase in the death rate of nodes. Consideration of residual energy and avoidance of looping path make DSIP consume minimum energy and provide an enhanced lifetime for the nodes. Respective values of Figure 4 are provided in Table 5.

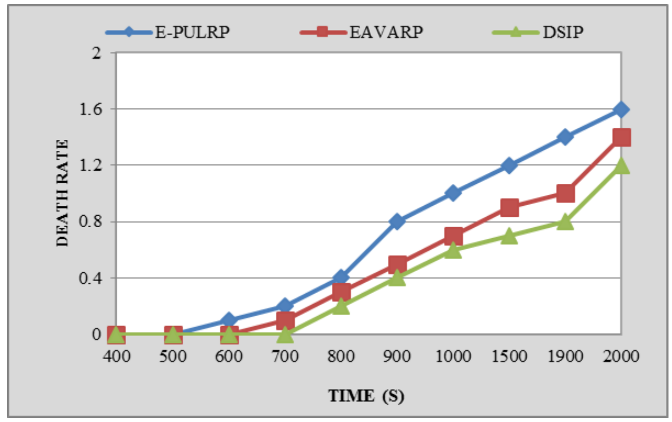

Figure 4 DSIP Vs Death Rate of Nodes

Time	E-PULRP	EAVARP	DSIP
400	0	0	0
500	0	0	0
600	0.1	0	0
700	0.2	0.1	0
800	0.4	0.3	0.2
900	0.8	0.5	0.4
1000	1	0.7	0.6
1500	1.2	0.9	0.7
1900	1.4	1	0.8
2000	1.6	1.4	1.2

Table 5 Node Death Rate

5.4. Packet Delivery Ratio Analysis

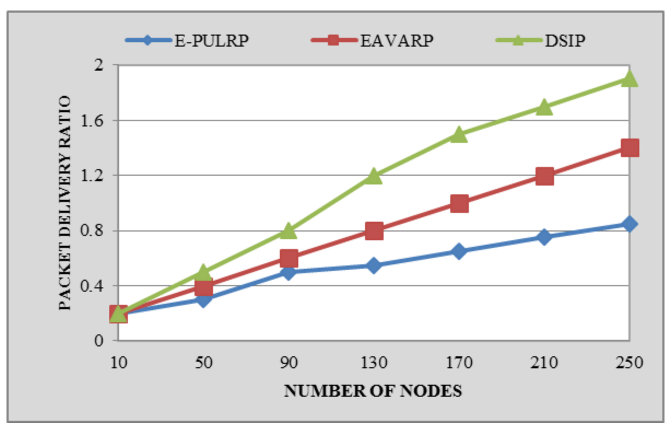

Figure 5 DSIP Vs Packet Delivery Ratio

Figure 5 demonstrates the relationship of DSIP with the number of nodes and packet delivery ratio. When the count of nodes is increased, the packet delivery ratio also gets increased automatically. But after reaching a certain limit of nodes, the packet delivery ratio begins to decrease. Till 90 nodes, all protocols have given an increased packet delivery

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ratio. But, after 90 nodes, E-PULRP and EAVARP started seeing very low progress in delivering the data packets. The predation phase of DSIP assists in adjusting the energy level of individual nodes while they have maximum energy. DSIP enhances the packet delivery ratio by identifying the neighbor nodes where it avoids loop path and error route to the destination. Respective values of Figure 5 are provided in Table 6.

No. of nodes	E-PULRP	EAVARP	DSIP
10	0.2	0.2	0.2
50	0.3	0.4	0.5
90	0.5	0.6	0.8
130	0.55	0.8	1.2
170	0.65	1	1.5
210	0.75	1.2	1.7
250	0.85	1.4	1.9

Table 6 Packet Delivery Ratio

6. CONCLUSION

In this paper, bio-inspired routing protocol namely DSIP has been proposed for UWSN. DSIP involves 4 different important phases namely searching, calling, reception and predation. The four different phases are inspired from natural characteristics of dolphin and it is applied to find the best route to destination. DSIP makes sure the validity of link and topology of network which assist in finding the best route in dynamic environment. Preference is given to every node during data transmission which assists in avoiding loop path and providing better efficient route. Residual energy is considered by DSIP before it forwards data packet to next node which helps in avoiding the flooding of messages and error. Moreover, DSIP balances the energy in all the nodes in UWSN to extend the lifetime of network. The current research work is evaluated using the parameter network size and obtained better results than existing protocols. Its performance can get degrade when it is tested with different parameters. Future dimension of this research work can be focused with different bio-inspired optimization techniques and can be evaluated with different parameters.

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