Underwater Pragmatic Routing Approach Through Packet Reverberation Mechanism

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ABSTRACT The advances in underwater sensor communication has become imperative getting up-to-date information about underwater happenings, especially when world has already faced the calamity like Tsunami. The underwater environment possessed freak and unpredictable movements which becomes more harsh time to time. The sensor nodes deployed under such juncture are the main source of information which in fact, facing numerous challenges. These nodes are mainly energy-constrained and rely on limited battery source. Due to most intricately underwater routing architecture, the biggest detriment is the limited battery lifespan. Therefore, it is imperative to adopt the pragmatic and possible alternate to improve the life expectancy of these sensor nodes. The solution of such shortcomings and identifying the varieties of impingements impelled by forwarding node on battery lifespan during packet transmission course are meticulously explored by developing an Underwater Pragmatic Routing Approach through Packet Reverberation mechanism (UPRA-PR). It is a novel approach and never considered in past. Through Packet Reverberation technique, the use of energy has been confined and the desired outcomes are achieved in four phases. In the first phase, the eligibility criteria for both packet and nodes have been computed by setting the Node Depth Factor ($N_{df}$). Second phase formulates the forwarding relay node mechanism and rummage out the path failure by complying a Data Rate criterion $D_0$. The selection of the shrewd communication link is established in third phase by considering an Accepted Link Quality (ALQ) factor. The fourth phase where most prominent developments has been made regarding impingements effects on the battery lifespan left by the forwarding node after the packet transmission. The UPRA-PR performance metrics are assessed by staging extensive NS2 simulation with AquaSim 2.0 and compared to state-existing routing protocols i.e., DBR, H2DAB, GEDAR and FBR for Packet dissemination ratio, Path failure, Point-to-point delay estimation, System energy consumption, Network lifespan, Forwarding node impingement and Network throughput. The simulation results have ratified the UPRA-PR performance and justified the statements made in this respect.

INDEX TERMS Packet reverberation, opportunistic routing, dearth node, energy efficiency, network throughput, forwarding relay node, sagacious link.

I. INTRODUCTION

Underwater wireless sensor communication is facing countless hassles in packet transmission. Some exorbitant challenges for instance are, uncouth energy consumption, severely restricted bandwidth, higher propagation delay and escalated attenuation perdition degrades the performance [1]. Power source mainly relies on batteries accompanied by the sensor nodes which are highly energy-constrained and there is no recharge mechanism except replacement which is actually rising to higher energy costs [2]. Achieving high network throughput has always remained a verdant target while
minimizing the packet delivery error ratio. A multi-hop wireless routing protocol could forward the data packet directly towards next neighboring node, there is a great chance that the selected node might not overhear the packet when wireless link is not stable even if it’s probably the pristine link; the sending node will try to retransmit the packet at another time. A wireless network channel encompasses the shrewd data forwarding nature thereby, all neighboring nodes dope out the packets in specific transmission range with delivery acknowledgment [3].

In fact, underwater communication is a unique broadcast phenomenon, researcher found that when a packet is being forwarded from source to neighboring nodes, a priority-based node selection criterion is followed to opt-in the near most node as a preceding hop forwarder; therefore, all packets are routed through this forwarder. A sensor node broadcasts the data packet towards neighboring node to discover locations and build the transmission path within specified range [4]; thereupon, multiple paths are created, and transmission accomplishes through these available paths. Consequently, data packet reaches to destination sink node passing through variable intermediary nodes, this unique phenomenon of packet transmission is called the Opportunistic Routing (OR) [5]. An opportunistic routing reduces the retransmission iterations and confine the energy utilization [6]. If the transmission path becomes unavailable, thereby packet forwarding can be accomplished by alternate paths. This entire phenomenon indeed happens through the selection of dynamic relay node which accompanied by multiple forwarder that overhear packets from sensor nodes.

However, the performance of the generic OR protocol depends primarily on the following factors.

- **The algorithm that selects the forwarder and arrange the nodes in priority queue**: Every source node is surrounded by various neighboring nodes and possesses unbalanced residual energy, the dynamic depth and uneven link quality [7]. The OR algorithm tries to opt-in the best forwarder node by considering aforementioned metrics in addition to the lowest packet holding time thereby only pristine node can forward the packets [8], while rest of the nodes hold the packets in accordance to the packet forwarding priority criteria. The nodes holding packets must forward the same packet until specific holding time becomes unavailable without further listening to the forwarders of the same packet.

- **The coordination mechanism between nodes**: Within transmission range, by fixing the transmission schedule, all nodes carefully comply with coordinate pattern for receiving and transmitting the packets simultaneously which graciously broaden the transmission process.

Generally, for underwater communication, all sensor nodes are deployed in two-dimensional and three-dimensional topological architecture.

### A. SENSOR NODES DEPLOYED IN TWO-DIMENSIONAL ARCHITECTURE

All nodes are responsible for sending data packets have deployed with physically connected wires (Anchored) at variable deployed positions whether in ocean bottom or at intermediate places [9]. Communication is carried out through acoustic signals among all the nodes. These node delivers data packet to sink node locating as a buoy, at upper water surface via immediately nodes [10]. The sink node further transfers the data to the offshore stations. A sink node is fabricated with two transceivers i.e., horizontal and vertical. Through horizontal transceiver, it communicates to deployed sensor nodes for collecting and controlling the information while vertical transceiver delivers the collected information to offshore station. An offshore station shrewdly controls the parallel communication with sink nodes and to long range satellite transmitter with the help of acoustic and radio transceivers respectively [11]. There are myriad straining challenges faced by Two-dimensional deployments as, (i) sensor nodes in exact quantity been deployed to achieve the expected output. (ii) selection of shrewd deployment location, must be provided with linkage area at the bottom. (iii) Incase of link failure, the alternate measures to overcome the situation.

### B. SENSOR NODES DEPLOYED IN THREE-DIMENSIONAL ARCHITECTURE

All sensor node including surface buoy floats at various arbitrary spots for sensing the information [12]. Sometime, unique approaches are taken into account, for example wire-binding nodes to surface buoy, this approach is best suited for limited zone, but becomes vulnerable during shipping vogue and uncouth aquatic movement. In addition, it is not cost-effective because wastage of anchored-wire and repairing cost eventually increases the deployment budget thereof; sometimes detriment of losing sensitive information. This architecture has vacillating challenges, such as (i) sensing coverage depends on the availability of nodes thereupon full coverage is inoperable in dynamic environment. (ii) Sensor routes data through multi-hop routing, the selection of shrewd routes and data forwarding nodes are extremely complicated task that cannot guarantee which routes are foremost suitable and topology of the network always be linked [13].

Senor node communicates directly with sink buoy can never be a shrewd task when myriad distance present among the nodes [14], which thereby consumes exorbitant energy and batteries are drained-out in a short while. On the other hand, direct link is a cheapest solution for data delivery [15], which not only improves the network throughput but also confines the end-to-end latency but suitable only for restricted use. In order to seize the strength of batteries, it is crucial maintaining the routing strategy in such a way that no real-time communication should be affected [16]. The researchers are working to take intelligent measures for OR enhancement and reducing the point-to-point delay during
packet forwarding process. The multiple forwarders rebut
the number of retransmissions that recognizes the single hop
forwarder selection at each intermediate node. The forwarder
selection and prioritization technique indeed determine the
performance of an opportunistic routing. An OR instigates
the operation by generating the bunch of packets from origin
to targeted sink node involve number of hops. It discovers the
neighboring nodes along the passage and debuts the packet
forwarding process. The selection of a forwarder relay node is
carried out through decision-making series; during first trans-
mission round, it is not possible to deliver direct packets from
source to sink. Therefore, accomplish the task smartly; nodes
forwarding packets to next qualifying relay nod by taking
into account the packet holding and forwarding mechanism to
next destination relay node. Eventually, packet successfully
reaches at final destination after each transmission round.
The transmission might confront by unreliable signal interfer-
ence, even though forwarding process remains continue and it
combines weak intersections together and generates virtually
strong intersections that allow a reliable transmission path
[17]. The novel concept of confine energy consumption are
associated with Expected Transmission Count (ETC) [18],
which reduces retransmission with unleashed communication
factors like energy, delay and link sustainability.

C. THE PROPOSED SAGACIOUS MODEL

The proposal has been put forward with the aim of using only
the trivial amount of energy by developing an Underwater
Pragmatic Routing Approach through Packet Reverberation
mechanism (UPRA-PR). The entire process heavily relies on
the selection of forwarding relay node and the impact left on
the battery performance. This impact is being determined by
taking into account the Packet Reverberation process, which
ultimately plays a vital role for saving the node energy. The
entire operation consists of four phases, in which the data
packets from source to sink are successfully transmitted, as illustrated in data flow chart Fig. 1. The operation debates
initially, by identifying the path losses; if acoustic channel
comply to proposed data rate criteria $D_p$, thereon, acoustic
signal will propagate without any hindrance, regardless of the
fading channel capacity, otherwise these signals seem to be
maverick or some ambient noises which will ultimately be
ignored. All neighboring nodes will overhear the transmitted
packet and verify whether it is a qualified packet or not followed by the packet eligibility criteria by calculating the
Node Depth Factor ($Ndf$), if this factor found higher than the
residual energy RE of that node for instance node $i$, considered packet belongs to same transmission zone and can be
taken for forwarding operation otherwise it will be rebuffed.
Similarly, the nodes locating at higher depth than the source
node cannot participate in packet forwarding operation and
will be ignored, these nodes are called Deprecate nodes and
its eligibility can be determined if the depth $Dh$ of source
node, for example node $i$, is greater or equal to the depth of
the neighbouring node, like node $j$, the node cannot participate
in communication and will be marked with cross sign as
illustrated in Fig. 2 of section 3. Proceeding to the next phase,
the (ii) shrewd link selection, using predefined Threshold
Criterion parameter $tc$, the communication links between
source and neighboring nodes are meticulously examined by
taking into stringent course in the form of Accepted Link
Quality (ALQ) which is based on Triangular Metric (TM)
and thereby, setups a repository namely called Link Corpus
Table (LCT) that proceeds further for estimating the quality
of communication links by computing the Link Quality Fact-
or (LFI) and Signal-to-Noise Ratio (SNR) having distance
factor $d\Delta$ between source and neighboring nodes. If ALQ
measures are found to be shorter than $d\Delta$ the packet will be
neglected again.

During the validation process of the nodes, some nodes are
found to be inactive or not overhearing packets within the
specified duration, these nodes are named as Dearth node.
In addition, there dearth nodes previously have served as
relay forwarding node and left stringent impact on battery
life therefore available with shorter residual energy right now.
The packet broadcasts from the source node when impinges to
dearth node thereby follows the (iii) reverberation process and
returns to the source node again. Consequently, if the dearth
node was unable to react quickly, it would assess its residual
energy state, which may help analyzing the effect left on its
battery life. In fact, it is accomplished by concentrating the
residual energy status of the dearth node in the due course of
before and after the packet transmission, in accordance to the
schedule-based S-MAC [19], wakeup and sleep mechanism.
The packet reverberation is routed back to the source node by
following the angle of dearth and source node ($\theta, \phi$) hence,
the level of impingement left on battery through residual
energy status is pragmatically analyzed by computing the $PR$
values. It is the most dominant feature in the course of rely
node formation. Next time, the source node will not broad-
cast the packets toward dearth node angle, which eventually
increases the packet transmission period and eliminating the
flow of excessive energy.

Finally reveals (iv) the principle $E_{f} (p, d)$ of confined
energy consumption after formulating the relay node. The
UPRA-PR key achievements in terms of network throughput
and packet dissemination ratio have been enhanced through
shrewd energy consumption ratio. Through packet reverbera-
tion, the impingement of forwarding node on battery lifespan
can be determined and therefore pristine achievements are
being made in relation to the path losses and end-to-end delay.
The shrewd algorithms have been designed in support of the
statements made during packet transmission for each phase.

Astute contributions to UPRA-PR research methodology
The sagacious contributions incorporating for efficient
energy utilization by UPRA-PR methodology are listed as
under.

- The key objective was to determine the impinge-
ments leaving on battery lifespan by the forwarding
node after the packet transmission has been performed.
The impingement consequence has been sagaciously
FIGURE 1. The proposed UPRA-PR data flow chart.
investigated through Packet Reverberation mechanism which is a unique phenomenon and no researcher could ever focus such aspect in the study during designing of energy efficient underwater routing protocol. The entire objective is accomplished in 4 phases.

• First phase (i) identifies the underwater hoodlum factors, causing hindrance for acoustic signal in linear propagation for instance, the packet routing path losses that creates an extra burden upon the batteries.

• Second phase (ii) initiates the packet legitimation process thereupon neither any maverick packet can receive nor be forward by the nodes. At the same time, by measuring neighboring nodes depth; a node legitimation begins which ensures that only qualified nodes can only participate in the transmission process.

• During third phase (iii), the link quality is determined through ALQ mechanism and thereupon chose only a shrewd link between source and destination node among the variety of available link qualities.

• Foremost, (iv) the UPRA-PR greatest contribution is the use of Packet Reverberation mechanism to explore impingements on battery performance by the forwarding node left after the packet has been transmitted, which is never addressed before.

The rigorous simulations are performed using NS2 and AquaSim 2.0 to investigate the performance of the UPRA-PR methodology against the existing underwater routing protocols like DBR, GEDAR, H2DAB and FBR. Remaining findings are arranged as; classification of opportunistic routing and critical comparison among various underwater routing protocols are addressed in section II. Section III presents the proposed methodology with details of four phases. The performance analysis and results are placed in section IV. Section V is included with post result discussion. The conclusion and future research directions are highlighted in section VI and VII respectively.

II. RELATED WORK
The energy adaptability is a rigorous challenge for UWSNs. Foremost, the acoustic channel consumes exorbitant energy than other transmission media. Although numerous routing protocols are claiming as energy-efficient but demands distinct routing pattern. In fact, these protocols are not cost-effective and engulfs energy resource uncouthly [20]. The shrewd transmission link quality is not being considered by most routing approaches thereby impinge the great impact on the battery life, consequently receiving the hollow links that result as energy wasted cycle. Opportunistic routing involves multiple forwarders to overhear the data packets that each intermediate node not only reduce the number of retransmissions but also comprehend each forwarder hop.

Coutinho et al. [21], developed an underwater topology control mechanism to resolve the power control issue at each sensor level. He further proposed a transmission scheduling model that aims to conserve energy and increase the network throughput by keeping the channel bandwidth as a relative
instance and measuring the distance factor. To prevent collision, the transmission link scheduling system is adopted, and the power control scheme is introduced that reduces the transmission range to prevent the tangling communication links. This algorithm however, converted the narrow bandwidth and made poor quality of the connections. This principle is only accepted for short range network, and in the course of the transmission power control system, no proper transmission effect has been discussed.

A cross layer design issue has been worked out by Yang et al. [22], that aims to mitigate energy usage and extend the life of the network. The factors such as, link scheduling, transmission power, and transmission rate are carried out with time division multiple access. The aftershocks of power optimization are presented and intending handler are applied using the interactive algorithm in linear and rhombus topologies but have not mentioned any formal clue in the results. Due to sudden displacement of nodes, it presages that scheduling becomes out of order and algorithm do not present such activity and become futile in nature.

The impact of forwarding node has been proactively analyzed with angle based power efficient mechanism proposed by Ashraf et al. [23], carries the packet transmission by considering the forwarder hop angle (FHA) and the Counterpart Hop Angle (CHA). A three-state link quality check has doped out, the targeted forwarding relay node among the neighboring nodes; which analyzed how much batteries are draining out by the forwarder node when a packet has been transmitted. This link quality metrics is adopted with predefined values using Additive-Rise and Additive-Fall method. This method increases the probability of packet collision. Therefore, no proper impact measures are addressed further.

Kim et al. [24], implied a transmission power model relative to perceive the channel sustainability. Throughout modification of transmission power, the power impact has been analyzed by changing waves amplitude because height of the waves influence the reflection of the surface signal and the frequency of the signal transmitted. The estimated value can be used to measure the height of the wave root mean square (RMS). The transmitting capacity of all the nodes and respective frequencies should be proportionately balanced to the wave height RMS which cannot be seen in results. The authors claim that adopting such mechanism could dwindle the substantial amount of energy consumption thereby nodes’ transmission power can also be reduced but when wave height reduced sluggishly to the empty level no effective measures are addressed to handle this atrophy condition which may create congestion in network.

The impact of transmitting capacity is addressed in the controversial MAC protocol by Qian et al. [25], where data packets can be transmitted using trivial power. This contention-based approach can reduce the packet collision at an acceptable level but when node seeks large capacity transmission power for RTS/CTS packets the sudden energy dump could lead to node shutdown that still has to be addressed.

Cao et al. [26], proposed a Balance Transmission methodology BTM by dividing transmission in two segments and thereby impact of transmission is also divided. The node assessment carrying single or multi-hop propagation depends on the energy level of the neighboring nodes. When the intensity level of the surrounding node is below than the level of the transmission node, the direct single-hop data transfer to the sink is performed. Additionally, data is transmitted through multi-hop transfers to the destination sink. This system will reconcile the use of energy across two competing nodes. Nonetheless, there is only one relay node in every network, and sometimes unrealistic transmission occurs. As traffic and nodes are unevenly distributed thereby battery transmitting effect goes out.

A power efficient routing scheme (PER) has been proposed by Koul and Kour [27], that incorporates the forwarding tree trimming mechanism to analyze the effect of transmission loads and prevent the energy from flooding. It consists of three metrics and picks up only two packet forwarding sensor nodes. The range and angle between the two adjacent sensor nodes and the residual energy remaining in the sensor node are determined by three metrics for the forwarding node selection. In order to assess the impact after the packet has been transmitted, the authors were unable to provide a static analysis of any residual energy within the node of the sensor by taking into account the distance or depth metric up to the node.

No doubt, supplementary measuring tools used for this purpose drastically increases the energy consumption. Further, two sub-classes of Location Free routings such as, beacon-based and pressure-based are available, also called depth-based routing. After packet forwarding, the forwarder node impingement left on the battery life relative to the location based opportunistic routing protocol is pragmatically investigated.

A. LOCATION BASED (OR) FORWARDING NODE IMPINGEMENT

The prime metrics of closely related state of the art position based opportunistic routing protocols during packet transmission with energy consumption vectors are thoroughly explored and thereafter the stern challenges in terms of Forwarding Node Impact (FNI) has been explicitly revealed and needs to be addressed in future results.

1) Vector Based Forwarding (VBF) [28]: It is a unique location dependent protocol with shrewd concept of virtual pipeline between source to destination sink node. The packets are being forwarded through pipeline and thereby losses are tracked with link failure mechanism. It can well manage the routing mobility thereon each packet includes source, forwarder and destination location details. Once a node accepts the packet, its location is determined. If the estimated location lies inside the pipe, thereafter the node implants the location information into the packets and transfer the packet to next forwarder, else it rebuffs the packet. This maintains
higher energy efficiency because the protocol restricts the forwarders range within data transmission.

**FNI analysis relating to battery life:** In case of sparse network, the chances of void communication seem higher which eventually leaves the drastic impact on transmitting node and three-way handshaking mechanism causes major power consumption which drains out the batteries very quickly and hindrance the packet delivery ratio. Therefore, no specific measures available while dealing with FNI tribulations. It is essential to update the VBF to overcome this issue.

2) Directional Flooding-based Routing (DFR) [29]: It considers the consistency of connected packets between source to endpoint and each node identifies the next-hop location. Selection of forwarding nodes are depending on the nature of the connection and the angle of arrival. This angle maintains the restricted zone thereon receives the packets in flooding cordon from the source node. It must maintain a single forwarder throughout the flooding zone to minimize the packet disruption failure. Though it addresses the situation wisely when only worst links are available by extending and adding more forwarder nodes and the transmission zone respectively.

**FNI analysis relating to battery life:** Expansion in transmission zone gradually dwindles the batteries performance and thereupon FNI remains unresolved and no alternate solution is recommended yet, and If the network is substantially overloaded the redundant packet generation will increase the processing tangle.

3) Focus Beam Routing (FBR) [30]: Every node must possess own location information and the location of final packet destination. Based on the transmission frequency, the forwarding area is chosen. If no node appears in the transmission zone, the transmission power would be increased. The source node applies several power metrics to communicate directly with neighbors and commences at either the lowest energy level and rises until it gets response from desirable neighbors. As the selection of relay nodes is made within restricted zone thereby, protocol might not function in scattered environment effectively.

**FNI analysis relating to battery life:** The increasing transmitting power from lowest to higher will twitch the batteries power thereby node seems to died earlier. There is no power system capable enough to prevent the overloading of batteries thus, the FNI increases time-by-time.

4) Geographic and opportunistic based Depth Adjustment Routing (GEDAR) [31]: Using neighboring location information which forwards data packet by picking a bunch of next-hop forwarder nodes; In order to prevent unwanted transmission, the low priority node blocks transmission if they detect a high priority node sent to the same packet. It unfolds a unique recovery technique for void nodes, transfers void node in new levels to begin geographic mapping as per requirement. For any stage when data packet gets stocked, the void packet recovery mechanism invokes which alter the depth location of the void node.

**FNI analysis relating to battery life:** The recovery strategy engulfs the unparalleled energy, which immediately impacts on battery performance and causes amortized after-effects therefor, no other approaches to test the FNI are suggested.

### B. LOCATION FREE (OR) FORWARDING NODE IMPINGEMENT

The sensor nodes belonging with this class of underwater routing are further categories as beacon-based and pressure-based UWSNs, mainly utilizes a built-in pressure sensor to calculate the water level in specific region. Thereupon, such protocol does not include the details for organizing two-or three-dimensional location. A location free OR class identifies the hop-count suburb node with dynamic address and pressure information. From the beacon-based subclass, the sink node generates the time-based beacon data messages, these messages are carrying across the water surface to the depth that contains the unique identifier called dynamic address. For multiple network topologies, various beacon-based protocols are used having different address information allocated to the sensor nodes. Location free OR utilizes topology details to explore forwarding nodes which makes the network conveniently scalable. Regarding rationalization factor, the depth or the pressure information is essential that a pressure sensor can easily obtained. These methods typically enable the discovery of wide seaside regions rather than a small field. In order to determine the FNI detritus left on the battery lifecycle and energy utilization in terms of location-free opportunistic routing protocols, the functionalities of such relative protocols have been discussed explicitly.

1) Depth-based routing (DBR) [32]: This requires sensor node mobility to make underwater communication wide scalable. The pressure sensors are used in support to forwarders; incorporating this capability, node activities for rolling waves will not require to adjust the position of sensor nodes. There are five static sinks on the water surface and two source nodes in the backbone network. Source node detects the required component during flooding which forwards data packet to the sink. Each node incorporates its depth and Id details into data packets. On submitting data packets, each node called a retention time which is kept over a certain duration. A forwarding node will only send the packet if it is generated by the node from a greater depth node than its own otherwise rebuff it. The DBR has a pragmatic packet transmission mechanism and possess a pause owing to the selection of the lower-depth nodes as relays.

**FNI analysis relating to battery life:** It suffered by redundant packets and overloaded nodes close to the sink node. These nodes will soon die and builds the network energy holes. In the later stage, these holes compromise on battery efficiency and thereon no recovery or alternate approaches are available to measure the FNI impingements.

3) Hop-by-Hop Dynamic Addressing-Based Routing (H²DAB) [33]: This greedy nature protocol does not require additional hardware unlike other protocol belongs to same class. Many stationary sinks are located on the water surface, while other nodes are at the bottom of the sea. The depth of the ocean is segmented among several levels while regular nodes...
are installed for floating control. Such nodes can easily displace horizontally but never vertically. It works for dual phase in the first step, all floating sinks are given a dynamic hop IDs to start sending hello packets down to the bottom surface. Any receiving node must change its hop ID to that of the sink node. Every forwarder node therefore sends an application message to the surrounding nodes. A node with smaller hop identifiers is chosen as a next hop node. The whole protocol not only manages node movement but also uses a multi-sink architecture, which suppresses congestion at nodes closer to sink. So far as energy efficiency is concerned, this protocol has several disadvantages for instance, deployment of mobile nodes at various positions and this deployment becomes more complex with other random deployment phase. Further, communication void leads to have energy wastage.

**FNI analysis relating to battery life:** The high packet loss and poor communication links are causing exorbitant power flow which shorten the network lifespan and no forwarding node impact has been pointed in algorithm neither discussed in the results.

4) Energy-Efficient Routing Using Physical Distance and Residual Energy (ERP²R) [34]. This protocol assigns a perpendicular from source to sink node and puts through, link cost estimation for every node depending on physical distance to the sink at upper water surface. Thereupon, sink node reverberates a Hello message toward its neighboring node, containing IDs, residual energy and distance cost. All node obtains statistics about the residual energy of their neighboring nodes. Each forwarder node integrates and transmit a sorted list of its neighbors detail. In addition, the IDs of those adjacent nodes with cost below the level of forwarding nodes are listed accordingly. Thereupon, the list is sorted on the basis of residual energy where each node with more energy has a higher priority.

**FNI analysis relating to battery life:** In a dense network, the numbers of next hop nominees are significantly rising which exacerbate the energy consumption cycle and becomes higher risk for the batteries. Even though, using a multi-sink mechanism to avoid the quick depletion of batteries power for the nodes nearer to the sink node, but no improvements regarding FNI are achieved.

5) Energy Efficient Depth Based Routing (EEDBR) [35]: In addition to the depth metrics, this protocol addresses the residual energy of node against the consequence of the horrible death of low-depth DBR nodes. If a sender node is essential to choose a forwarding node, it must pick the lowest depth having greater residual energy forwarder, from its one-hop neighbors. It includes a chart of the neighboring nodes, knowing as forwarders with smaller depth. When data packet has received; thereon the first node in the chart instantly forwards the packet without further delay. Afterward, the remaining forwarding nodes in the chart hold the packet. The random numbers are created by the forwarding nodes while overhearing the duplicate packets from thereabout nodes during a retention time and compares the transmission ratio. In case, the random number founds lesser than distribution ratio, node disables the transmission, and packet will be transmitted. If packet is being transmitting while retention time is just to expire and no packets have been overheard. This helps to energy conservation and prevents energy losses in during transmission.

**FNI analysis relating to battery life:** This protocol does not guarantee the data reliability at the destination point. This is because the next forwarder in EEDBR is only determined by a sender node and no FNI measures have been taken at any state, which hoist the risk of packet failure.

6) HydroCast [36]: It is a pressure dependent OR protocol and possesses the geographical recovery mode. All nodes are occasionally scattering and fabricated with pressure sensor measuring own depth locally. Routes to the sink nodes are deemed by considering the depth information at various depths. Similarly, it incorporates the subset of the surrounding node and advances towards sink node. Considering the Expected Packet Advances (EPA), used to identify the higher quality adjacent and hidden node problem to prevent packet duplication forwarder, toward subset nodes. When the same packet moves from a higher ordered node during the retention time, it curtailed the forwarding to prevent the duplicate packet transmission.

**FNI analysis relating to battery life:** Calculating distance information from neighboring two-hop nodes to choose the series of forwarder nodes and estimating the distance by ToA of neighboring two-hop nodes causes high overhead communication. This eventually, leaves the greater impact on battery performance and no attention is given during literature study. Further, because of myriad node displacements in underwater configuration, the alternate routes are explored by the local maxima node which expires in a less time. These detour routes in local maxima needs repeating cycle that increase the transmission overhead and thereby no FNI impacts are addressed in the entire due course.

### C. SHALLOW TO DEEP WATER ACOUSTIC PROPAGATION

The underwater economic climate is complex and dynamic in nature thereby, acoustic communication has often suffered from unpredictable variables due to that, the rest of the channel bandwidth depends merely on frequency and linking time. The functionality of the underwater sensor varies as shallow and deep water due to the division of the ocean [37]. The murky water includes, higher temperature, multiple legacies but with fluctuating dimensions. Some salient factors of shallow and deep water are handed in Table 1. In UWSNs, the geographical dynamic routing falls into three prominent categories, namely the unicast, anycast, and geocast. In (i) Unicast Transmission, the data packet transmits from source to the single receiver node and if inactive nodes are present in the network they do not participate in communication process [38]. For (ii) Anycast Transmission, the more than two different routing destinations have a common target
address. The desired path is chosen based on the number of hop size, the lowest cost, latency measurements or the least congested route. While a (iii) Geocast transmission, delivers information to the number of destinations in network classified by geographical locations. A comparative analysis among these transmission routings are placed in Table 2. A comparative analysis of proposed UPRA-PR methodology regarding selection of communication links and the impingement of forwarding nodes on battery performance with other state-of-the-art protocols is given in Table 3.

III. RECOMMENDED (UPRA-PR) METHODOLOGY

The selection of a priority forwarding node has always remained a stringent challenge upon which opportunistic routing algorithm relies. The proposed (UPRA-PR) model resurrects the UWSN lifespan by utilizing the confined energy metrics through packet reverberation mechanism. The proposed methodology meticulously analyzes the impact of a forwarding node left on battery life during transmission cycles. It dissuades the node to node delay and pragmatically dwindles the energy flow which tends to investigate the impact of relay node through contention-based MAC protocol called Sensor MAC or (S-MAC) protocol that fully supports the energy constraints for UWSN.

As S-MAC encompasses a time-based wake-up mechanism that regulates the living and sleep cycles of the specified duration. The S-MAC protocol is enough capable of handling collision and idle listening states; thus, energy wastage is essentially reduced. The proposed topology is illustrated in Fig. 2, a sink node with built-in acoustic modem is floating while modem communicates with relay node is deployed under water to grab the aquatic data. A sensor node broadcasts packet toward sink node; initially builds the relay node among the neighboring nodes within the transmission range. Sooner, every newly created relay node maintains its transmission zone and forwards the packet toward sink node which eventually traverses through several intermediate destination nodes and finally reached at the sink node. The depth of deployed nodes are normally ratified by an embedded depth-sensor while a Received Signal Strength (RSS) mainly estimates the distance among source and neighboring relay nodes [42]. Due to dynamic changes in the water currents, the sensor node suffers from insignificant displacements, thereby, energy consumption ratio becomes odious but adjusted later.

A. DETERMINE PACKET DWELLINGS

When sensor node debuts packet transmission and packet disseminate over the transmission zone thereby each zone is marked with unique identifier i.e., i, j, k, l and m. The nodes in their respective transmission zone are further marked by sub identifier IDs for instance, transmission zone i, contains node i1, i2, i3 and so on. These nodes overhear the packets from broadcasting node i and same procedure is followed by the nodes in other zones illustrated in Fig. 3. The nodes with crossed sign cannot participate in relay node selection process because their depth is higher than the depth of transmitting sensor node.

Aiming to determine the eligibility of the packet belongs to same transmission zone, a Node Depth Factor N_{df} has been introduced which ratifies the packet belongings by computing the energy metric expressed in Eq. 1.

\[
N_{df} = \frac{Dhi - Dhj}{R_{max}}
\]  

(1)

If the energy is found greater than the node’s residual energy, then packet will be accepted otherwise rebuffed. Here Dhi and Dhj together depicts the depth of the source and destination (relay) nodes, while R_{max} is a possible transmission range that packets can be reached at maximum. Each node from neighbor starts overhearing the packets and does make the subtle participation in N_{df} computation and same process will continue for all intermediary relay nodes until the packet reaches at destined sink node. The packet legitimation process is verified by pragmatic prevailing conditions defined in Algorithm 1.

Algorithm 1. explanation:

Node i, represents the packet broadcast active sensor node, which is surrounded by the neighboring nodes F(i). It has depth factor dh, for all F(i) nodes if their depth is higher than the node i, it will be considered inactive for packet overhearing and therefore marked with cross sign (line 2-4). Upon receiving packet, it computes N_{df}, if this value becomes greater than the residual energy of the node, it confirms that receiving packet dwellings within transmission zone or rejected if not the case (line 5-6) and consequently updates the lct table.
TABLE 1. Salient attributes of shallow versus deep water.

| Attribute             | Shallow Water | Deep Water          |
|-----------------------|---------------|---------------------|
| Temperature           | High          | Low                 |
| Depth                 | 0 to 100 meters | 100 to +1000 meters |
| Multi-path loss       | Only surface reflection | Surface + bottom reflection |
| Spreading factor      | Cylindrical   | Spherical           |

TABLE 2. Systematic review of unicast, anycast and geocast routing.

| Unicast                                    | Anycast                                    | Geocast                                    |
|--------------------------------------------|--------------------------------------------|--------------------------------------------|
| Functions with single sink topological architecture. Uses a one-to-one connection between source and destination node. A single receiver endpoint is uniquely identified by each destination address. | Functions in multi-sink environment. It is a one-connection in which data graphs are forwarded to each individual member of a group of potential recipients designated by the same target address. | It delivers the information to a target group in a network defined by their geographic locations. It is a specialized type of multicast addressing, used for mobile ad hoc networks by some routing protocols. |
| Designed for short range networks          | Preferable for large networks              | Ideal for large networks                   |
| Packet distribution is successful if the single sink received the packet | Packet distribution is effective if any sink receives packet | Packet transmission is effective if all the nodes within the geocast area receive the packet |
| With regard to the single sink, void communication is assessed | Void shall be determined in respect of all the sinks | Void communication is evaluated for the packet entry area of the geocast region |
| Number of paths from source to destination restricted | More paths from one source to another | The paths available depend on the coverage area across the geocast region |

Algorithm 1: Packet Legitimation Phase

1: Procedure PacketLegitmation (node$_i$, node$_{dh}$, R$_{max}$, pt)
2: for F(i) = {i1, i2, i3, ....... i$_n$} where dh = |F(i)| nodes with greater depth than node$_i$
3: ∀F(i), if node$_{dh}$ > node$_i$ // depth of neighbor node is higher than the source node + cross marked
4: elseif F(i) = (node$_{dh}$ + R$_{max}$) ← pt // depth of neighbor belongs to same transmission zone
5: Compute Ndf using Eq. (11)
6: update lct // Link Corpus Table
7: endfor
8: endif
9: end Procedure

B. STRUCTURING RELAY NODE WITH PATH FAILURE DETERMINATION

Moving to forwarding relay node formation, the packet transmitted by a group of sensor nodes, encountered in freak situation for instance, acoustic signals are confronted with an imminent hindrance similar to murky noises. Such uncouth sound barriers have significant impairment over acoustic transmission which creates a delay factor and eventually causes the path to loss. The sound wave propagates from particle to particle and behave like mechanical energy when transmitted from various sources [43]. The numerous unavoidable acoustic noises in different varieties must be calculated when designing the routing path. These ambient noises fall into four groups namely i).Turbulence N$_t$(f), ii). Shipping N$_s$(f), iii). Wave formation N$_w$(f) and iv). Thermal noise N$_th$(f) [44]. Taking advantage of Thorp propagation formula [45], for establishing underwater acoustic avenue, that can dwindle the sound intensity among source and destination nodes and could estimate the amount of noises and its elimination will yield the actual output. Initially, it is important to calculate the path losses (d$_{irj}$, f) from source to neighboring nodes i.e, i and j with route r over a distance d$_{ij}$ having frequency f. For proposed UPRA-PR approach, in order to determine the path loss during packet transmission, the extensive findings are summarized by the Algorithm 2.

Algorithm 2. explanation:

When packets are broadcast from source node i to neighboring node j, route distance r is calculated (line 2-4). It adds the node Ids, absorption coefficient and spreading factor and thereon determines the snr by Eq.(2) (line 5-6). Afterward, it calculates all unavoidable ambient noise using Eq.(3) that already mentioned during findings (line 7-9). By surrogating wind speed factor w, and comparing the distance and frequency (d$_{ij}$, f) of the acoustic signal generated from source to neighbouring node comply with data rate criteria D$_n$(line
| Category                  | Protocol                        | Expediency ground                        | Subject Region                      | Strategy for picking links                                                                 | Impairments                                                                 | UPRA-PR comparisons                                                                                          |
|--------------------------|---------------------------------|------------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| Location-based OR Forw.  | VBF by Xie et al [28]           | Robust, scalable, energy-efficient       | Distance information                | Pick the forwarder nodes inside the pipe from the source to the destination                  | Nodes throughout the pipe easily because of heavy data load, which produces holes in energy. Based on TM, ALQ makes the decision. | Using reverberation packet analyze the impact of forwarder node on batteries, no such strategy is available in VBF |
|                          | DFR by Shin et al [29]          | Mitigation of unfavorable channel conditions and high performance | Distance knowledge and consistency of the connections (ETX, severe restrictions on channels) | Defines a narrow forwarding zone created by the angle between the source, relay and destination nodes. | High power consumption due to flooding triggered by redundant packet transmission. ALQ takes into account the pre-defined threshold and thereby instead of angle it computes the Link Factor Estimator. | Reverberation Target Strength counts the amount of residual energy returned to source node.                   |
|                          | FBR by Joo et al. [30]          | Get the longest lifespan on the network with the highest competence. Perfect for networks including static as well as mobile nodes | Energy consumption and throughput   | The source node needs to be aware of its own location and its actual destination location, but not those of other nodes. Its routes are set at various transmission rates on demand. | It uses a standard transmission tube, occupying just a portion of the area of communication. Needs retransmitting RTS if a candidate node cannot be located within its transmitting ring. The absolute transmission packet and the successful acknowledge packet makes the link selection process easier. | The reverberation packet returns with death node residual energy estimation depends on the covering area in which the death and source node are located |
|                          | GEDAR, by Ghassan R et al [31]  | Power utilization, void communication area | Unsound energy consumption          | Selects forwarder nodes relying on packet development.                                       | Difficult to identify a neighbor's list, unbalanced energy usage, prevents nodes near to the surface of the body, contributing to unbalanced energy consumption. | Link Corpus Table maintains the status of newly created communication paths.                                      |
|                          | RMTG, by Dikshuwar et al. [39]  | Fast packet delivery using previous hop handshaking | Avoid large overhead in the network, creates the most efficient shortest path tree. | Calculate the distance between the adjacent nodes and select the link based on the destination closest. | Cannot handle the void area, constructed tree cannot cover all. If output exceeded by an appropriate quality level, the node and the connection parameter are held in the target nodes, like the leaf nodes.-selector repository, prevents duplication. | Ideal for dense and sparse network.                                                                           |
|                          | HH-VHF by Nicolae et al. [40]   | Energy-efficient, the biggest number of packet receptions in the sink node robust | Distance information                | Neighbors placed inside each single pipeline from each source to destination                  | Shortest lifespan network. Enlarge the competition delay. Selecting the consistency of the connection prevents bottleneck. | Next time source node will stop transmitting the packet in the directional angle to the death node after first encounter |
| Location-Free OR Forw.   | DMB, by Khan, M et al. [32]     | Scalable, energy efficient, shorter holding time | Greedy routing technique            | Uses lowest depth sensor nodes to forward packets from bottom to top.                          | Higher energy depletion due to redundant packets, high end to end delay, void holes, duplicate transmission. link selection is bound by the ALQ. | The effect on the battery efficiency contributes to the time of network response.                              |
|                          | H2-DAH, by El-Bakhouchi et al. [33] | Robust, scalable, energy efficient       | Address information, works in two phases | Neighbors with lower dynamic address, link is formed in keys steps.                           | First phase must be accomplished in a short while, link quality is not considered, RTS/CTS engulf the high cost energy. Incorporating SNR to received signal and the background noise do not influence the link selection condition. | Reverberation packet knocked back to source node with a strong violence scattering layer so that Dearth and Source node beam patterns are calculated |
|                          | HRP2R, by Ali et al. [34]       | Reduces the number of redundant transmissions | Based on physical distance and residual energy | Sender node decides the forwarding group.                                                    | Higher energy consumption for dense network.                                                                          |                                                                             |
|                          | Hydrocast, by Khanzadeh et al. [36] | Energy balancing, avoid redundant packet transmission, void recovery mechanisms | Dead and recovery approaches are used for packet transmission | Utilizing EPA for link selection.                                                             | In sparse conditions, compromised output. ALQ determines the packet advancement towards the surface sink. The FNI estimates the effect and can presage the time to revitalize. |                                                                             |
|                          | DSRP, by Yalda et al. [41]      | High throughput                         | Uses dual path, Mobility of Node     | The location and velocity changes of the nodes are used to send the packets to the sink.        | Large usage energy and excessive interval. Low-priority links are set behind. Dearth nodes utilize a schedule based alive and sleep mechanisms |                                                                             |
Algorithm 2 Path Losses on Lineup

1: **Procedure** Compute Path losses ($d_{ij}, f$) // distance over frequency
2: $d_i$ = source_nodei.distance
3: $d_j$ = neighbour_nodej.distance
4: $r = $ route = $d_A (i, j)$
5: **Include** $(D_{0x}a(f) + k)$ //data factor, absorption coefficient, spreading factor
6: Compute SNR using Eq.(3) for each factor
7: for each Tip and $N_T(f)$ // transmission impulse + ambient noises
8: Compute $N_T(f)$ by surrogating $(N_i(f) + N_s(f) + N_w(f) + N_{th}(f))$ using Eq.(4) //ambient noises
9: end for
10: **Include** and wind speed using Eq. 4 – 7 // ranging from 0 – 12 m/s.
11: If $N (d_{ij}, f)$ $\geq$ $D_0$ and $w > 0$ then
12: $F(i) = A(d_{ij})$ // $F (i) = $ source nodes
13: end if
14: end Procedure

10-12). Qualifies that the acoustic signal will be spread out without any loss of direction if $D_o$ is fulfilled and therefor, mathematical model has been given which debuts with Eq.2,

$$A (d_{ij}, f) = D_{0}d_{ij}^k\alpha(f)^{d_{ij}}$$

(2)

here $k$ is a spreading factor with $D_o$ as a data rate normalizing factor while $\alpha(f)$ indicates an absorption coefficient. By computing Signal-to-Noise Ratio (SNR) [46], with signal variations can be as expressed as Eq. 3.

$$\Phi (d_{ij}, f) = \frac{T_{ip}}{N_T(f)d_{ij}^k\alpha(f)^{d_{ij}}}$$

(3)

where $T_{ip}$ and $N_T(f)$ represents the transmission impulse and the ambient noises respectively. Summing up all aforementioned ambient noises in $N_T(f)$ thereby yields the result with Eq. 4 as,

$$N_T(f) = N_i(f) + N_s(f) + N_w(f) + N_{th}(f)$$

(4)

finally, the estimated amount of each noise during transmission cycle can be stated by numerting equations 5, 6, 7, and 8. Adding $w$ as a voyageing factor and encumbering wind speed arises by $0-12$ m/s.

$$10logN_i(f) = 17 – 30log(f)$$

(5)

$$10logN_s(f) = 40 + 20(s – 0.5) + 26log(f)$$

$$– 60log(f + 0.03)$$

(6)

$$10logN_w(f) = 50 + 7.5\sqrt{w} + 20log(f + 0.4)$$

(7)

$$10logN_{th}(f) = (– 15 + 20)log(f)$$

(8)

If these noise factor exists at large thereby, more precise estimation can be achieved by binding with Normal distribution [47], which can be expressed as Eq.9,

$$N (d_{ij}, f) = log_2(1 + \Phi(d_{ij}, f))$$

(9)

from this result Eq. 9 no matter, whatsoever the fading channel may be, the acoustic signals will propagate in all circumstances if the channel complies to $D_0$ given in Eq. 10. It eventually vouches the statement made earlier in the due course of acoustic pollution determination while keeping residual energy and depth information as a crucial factor indeed.

$$N (d_{ij}, f) \geq D_0$$

(10)

C. SELECTION OF SHREWDLINK

Generally, longest route adjacent to source and the neighboring nods $d \Delta$ foretells the best quality path but not a legitimate shrewd link. Therefore, a pre-defined Threshold Criterion $tc$ has been adopted by exploring the Accepted Link Quality as given in Eq. 11, taking Triangle Matric (TM) [48], as a base point, a Link Corpus Table (lct) is being setup to maintain and improve the threshold for appropriate link factor. For this purpose, let consider $pt$ as a absolute transmitted data packet and $ps$ being the successful acknowledged packet by the destination node. Consider $pti$ as the packet used to estimate the quality of the links by calculating Link Factor Estimator (lfe) and Signal-to-Noise ratio (snr) of $pti$ in accordance to the designed zones. The $lfe$ parameter can be calculated by Eq. 12.

$$ALQ = \begin{cases} Shrewdlink, & tc_{shrewd} < d \Delta \\ PristineLink, & tc_{pristine} \geq d \Delta < tc_{shrewd} \\ FairLink, & tc_{fair} \geq d \Delta < tc_{pristine} \\ Uncouthlink, & d \Delta < tc_{uncouth} \end{cases}$$

(11)

$$Lfe = D(p_{ti}, S) – D(i_{pt}, S)$$

(12)

The $D(p_{ti}, S)$ originally has taken from Euclidean distance formula i.e., from source node $i$ to the destination represented by $S$. The $i_{pt}$ represents the packet generated by the source node while $p_{ti}$ shows the packet creation due to the displacement effect of the neighboring nodes. When link quality reaches up to acceptable quality level thereby a fixing node and link threshold parameter will be maintained in LCT repository given in Table 4. The SNR incorporates the amplitude of the received signal and the background noise together and computes the signal ratio. Getting the $lfe$ mean, the SNR significaantly vouches that greater LFE and SNR threshold parameters will yield the scrumptious link.

**TABLE 4. Link Corpus Table (lct).**

| Metric type | SNR | LFE | Triangular scalability |
|-------------|-----|-----|------------------------|
| Shrewd link | >30 | >106| >145 |
| Pristine link | 15-30 | 102-106 | 80-145 |
| Fair link | 5-15 | 80-102 | 30-80 |
| Uncouth link | 0-5 | 0-80 | 0-30 |
The selection of shrewd connection between source and target nodes were examined by conducting a comprehensive test paradigm and thereby Algorithm 3. ratifies the result of the subject finding.

Algorithm 3. explanation:

The packet (packet \( pt \)) generated by the sensor node (node \( i \)) is disseminated over the entire transmission zone \((i)\), through initial communication link \((pt_{i1})\), which further expanding towards rest of the neighbouring nodes within transmission zone as \((pt_{i2}) \) and \((pt_{i2})\) and continue as illustrated in Fig.4. Further, the determination of shrewd link is performed by Accepted Link Quality, using extensive link testing mechanism and thereon came up with shrewd results (line- 5-23). Afterward, when shrewd link has been achieved between source and the target node, it further proceeds to form the relay node which specifically requires a stable communication link having unalter transmission power. Considering an absolute transmitted packet \((pt)\) and acknowledgment packet \((ps)\) and thereby computes the Link Factor Estimator \((lfe)\) and Signal-to-Noise Ratio (SNR) (line 28-35). Consequently, Link Corpus Table \((lct)\) is being updated with current status of the nodes.

D. PACKET RETENTION TIME

A time-based synchronization process is observed during \( N_{df} \) computation when the nodes are eager to wait for a relative period; in addition to time required to obtain, monitor and forward the packets by its high priority predecessors and thereby letting higher order transmission node to enter. The node must forward the packets even if the high priority node is not reached timely. To estimate the reserved time, the forwarding link selection process guarantee that all nodes overhearing the packet within same transmission zone acknowledge this by the \( N_{df} \) value. To prevent lengthy preambles in UPRA-PR the packet retention time will be assumed to the greatest distance across sender and the forwarder is relying on priority nodes. Therefore, if the packet has been broadcast, the forwarder node holding packet in compliance with the ALQ, thus giving
holding time as $Tr$. Eq. 13,

$$Tr(p) = \begin{cases} R_c - S_{max} \\ R_c + \frac{v}{p} \times S_{max} \end{cases}$$

where $R_c$ represents the communication range and $S_{max}$ considered as the maximum possible distance from source to forwarding node. Further, $P$ is pointing the forwarding priority in accordance to the position in the packet header, while $v$ indicates the acoustic velocity (1500 m/s) [49].

### E. ASSESSING FORWARDING NODE IMPACT ON BATTERY LIFE

Every time a forwarder node leaves odious impact on battery performance during packet transmission. With the passage of time this escalating impact becomes exorbitant which eventually expunge the battery and node causes to death. Using reverberation technique, the proposed methodology (UPRA-PR) presents a shrewd mechanism to determine the impingement of forwarder node left on the battery life after forwarding the data packet to the next hope node. In this scenario the former forwarding nodes having residual energy less than 20% are taken into account and namely called Dearth node as depicted in Fig. 5, and have a bidirectional communication link between source and death node.

![Forwarding node impingement.](image)

After getting residual energy level less than 20%, the dearth node becomes inactive and went into idle listening state in accordance to the contention-based S-MAC protocol. It could follow only periodic wakeup mechanism when overhears the broadcast packet but neither can accept the packet nor can participate in the forwarding. The packet captures the status of residual energy along with node Ids from forwarder active channel during triggers between fixed length of active and sleep states and reverberates the packet towards route ending to source node in the course of Reverberation Target Strength [50]. The information regarding amount of residual energy returned with packet can estimate impact of relay node left on the battery life. This estimation depends on the coverage area in which the dearth and source nodes are located. Next time, the source node will prevent to broadcast packets towards the angle of dearth node direction till the end of session. The reverberation packet area angle is depicted in Fig 6. Afterward, receiving Reverberation Packet (RP) by the source node can be expressed as Eqs. 14,15,

$$RP = SL + TS_{rev}r(\theta, \varphi)$$

$$RP = IL + TS_{rev}r(\theta, \varphi)$$

where the strength and impact of the level before and after packet transmission is represented by $SL$ and $IL$ respectively, and $TS_{rev}$ indicates the packet received target strength. The range between dearth to source node along with respective angles are denoted by $r(\theta, \varphi)$, when a reverberation packet knocked back to source node with a strong volume scattering layer, the level appears as Eq.16, the beam pattern for Dearth

$$RL = 10 \log \left[ \frac{D_o}{r^4} \int B_t (\theta, \varphi) B_r (\theta, \varphi) dA \right]$$

and Source node are marked by $B_t$ and $B_r$ accordingly, whereas transmitted Dearth level has been shown with $D_o$. The range between dearth to source node is marked by $r$, and $dA$ shows the distance element while signal scattering strength is depicted by $S_t$. The scattering strength is influenced by the angle of source node. The intensity of the
signal reaching to scattering zone and distance element can be determined by building Eq. 17,

\[ dA = \frac{C \eta}{2} rd \theta \]  
(17)

the magnitude of signal’s scattering strength, reaching to source plan dependents on dearth angle \( \varphi \). Letting the dearth and source node beam pattern same, and the source node angle \( \varphi \) yields maximum response thereupon, integral of the source angle becomes independent and exhibits the packet reverberation over non directive system as expressed in below Eq. 18, the second part of the equation represents an equivalent bidirectional signal beam width. If the returned packet becomes omni-directional to the source node thereby it yields result \( 2 \pi \) and expressed in decibel, called the directivity for reverberation expressed by the Eq. 19,

\[ R_d = 10 \log \left( \frac{2 \pi}{r} \right) \]  
(19)

further proceeding, the impact intensity received before and after the packet transmission is expressed as Eqs. 20-21,

\[ RP = SL - 40 \log (r) + 10 \log \left( \frac{C \eta}{2} r \theta \right) \]  
(20)

\[ RP = IL - 40 \log (r) + 10 \log \left( \frac{C \eta}{2} r \theta \right) \]  
(21)

by incorporating the distance element in terms of \( 2 \pi s_s \) becomes \( m_s \) thereby, the impact of the relay node before and after packet transmission could be yield by following Eqs. 22-23, the impingement of Forwarder relay node after packet transmission leaving on the battery life can now be determined in a distribution environment. Therefore, utilizing reverberation packet technique the proposed (UPRA-PR) methodology has achieved the pristine findings which could help resolving underwater routing challenges. The state of the art FNI Algorithm 4, presents the meticulous predictions of such impingements left by the forwarding node on the batteries.

\[ RP = SL - 30 \log (r) + 10 \log (m_s) + 10 \log \left( \frac{C \eta}{2} r \theta \right) - R_d \]  
(22)

\[ RP = IL - 30 \log (r) + 10 \log (m_s) + 10 \log \left( \frac{C \eta}{2} r \theta \right) - R_d \]  
(23)

Algorithm 4. explanation:

When the packet (packet \( pti \)) from source node impinges on dearth node (node \( H \)) gets no response within the stipulated time, it presages in idle listening state and fetches Ids and residual energy status from last transmission and adds new arrival time (\( t \)) (line 2-6). The Reverberation Process (RP) has been initiated and computes the SL & IL values which yields the Target Strength TS by Eq.(14-15), Line 10-12. Afterward, Computes the beam pattern (Bt & Br) for signal scattering by Eq.(16), (Line 15). The packet rovers through scattering zone and computes the reverberation signal intensity by Eq.(16),(Line 18). The impact intensity has been calculated before and after packet transmission by Eq. (20-21), (line 20-22). Thereafter, computes the impingement effect by adding distance element into impact intensity, (Line 24-26).

**F. PROBS FORWARDING RELAY ENERGY CONSUMPTION**

The proposed methodology efficiently adjusts the energy consumption during various activities for instance, sending and receiving packet with continue packet overhearing by the forwarder node. The energy consumption by each node during the transmission phase is exposed by Eq. 24,

\[ E_s (p, d) = \begin{cases} p.E_{ds} + p.E_{f,s d^2} \\ p.E_{ds} + p.E_{mp, d^4} \end{cases} \]  
(24)

where amount of consumed energy \( E_s \) send a \( p \)-bits beacon message over a distance \( d \), therefore, \( p.E_{ds} \) indicates signal dissipation and \( p.E_{f,s} \) depicts void space. The \( p.E_{mp} \) points the multipath representation. Upon receiving \( p \) bits energy shell from the source node and engulfs \( E_s \) energy when getting sensed data information, expressed in Eq. 25,

\[ E_p (p, d) = p.E_{ds} \]  
(25)

when a forwarder sends \( p \)-bits data packet to base station, it will consume \( E_f (p, d) \) energy given by Eq.26, the \( E_f \) indicates

\[ E_f (p, d) = p.E_{ds} + p.E_{fs} \]  
(26)

the energy consumption during packet transmission process. Consequently, Eq.27 extensively depicts the total energy consumption when the data packet is forwarded by the relay node to the destination sink node at water surface.

\[ E_f (p, d) = p.E_{ds} + p.E_{fs} \]  
\[ = 2p.E_{ds} + p.E_{f,s d^2} + 2p.E_{ds} + p.E_{mp, d^4} \]  
(27)

**G. MULTIPATH REFLECTION**

In murky water, there is multipath scattering [51], induced by boundary reflection which primarily increases the delay factor. The propagation of the multipath acoustic signal in shallow water is illustrated in Fig. 7. The sound propagation is disordered at upper surface, while it is impared by the bottom surface in deep water. The surface gravity also affects the propagation of the acoustic signals, particularly when modem signal impacts water surface negatively [52]. It is specular on both the volatile sea surface and the static bottom. The high-tech acoustic energy is surrogated by a vibrant surface, while water diffuses the bottom surface and induces scattering. Multipath generates braids with a strong
Algorithm 4 Impingement of Forwarding Node (FNI)

1: Procedure BroadcastingPacket (node $i$, node $i_1$, packet $pti_1$, $RE_{dn}$) // source node sending packet towards dearth node
2: $RE_{dn}$: Residual energy of dearth node at ($t$)
3: if node $i_1.RE_{dn} < 20\%$ then
4: node $i_1 \leftarrow$ idle_listeningState
5: add node $i_1.RE_{dn}, ID$ to packet $pti$
6: Set ($new.t$)
7: endif
8: end Procedure

9: Procedure ReverberationPacket ($RP$, $r(\theta, \phi), SL, IL$)
10: Compute $RP = r(\theta, \phi)$ // signal returns back to source node with dearth and source node angles
11: for $RP$ do
12: Compute $SL & IL = TS_{rev}$ using Eq. (14-15) // packet strength level and impact level received with target strength
13: end for
14: for$RLd$ do
15: Compute $Bt & Br$ for signal scattering using Eq. (16) // beam pattern of source and dearth nodes
16: end for
17: for $dA$ do
18: Compute $C_\eta$ signal intensity at scattering zone using Eq. (18) // distance element
19: end for
20: if returns $RP = r(\theta, \phi) =$ omni-directional
21: Compute $Rd \in 2\pi$ // distance element
22: Compute $RP = SL & RP = IL$ using Eq. (20-21) // impact intensity before and after packet transmission
23: endif
24: for $2\pi \times Ss \leftarrow m_s$ // adding distance element into impact intensity
25: if $RP = SL & RP = IL \leftarrow Rd$ then
26: $RP.(SL & IL) \leftarrow Calculate$ $RP$ impingement else
27: goto line 10
28: endif
29: endfor
30: end Procedure

FIGURE 7. Multipath signal reflection.

topological relationship with less diffused in existence [53]. The fluctuation in acoustic channel is driven by the ambient noises, fish movement and eddies.

All aforementioned factors, exacerbate the acoustic data routing. Apparently, author [54], suggested a partial multipath scattering approach by adding constant sound velocity $C$, and fixed depth $h$, which seems hard to achieve. In addition, the first and last boundary reflections of $n^{th}$ order of multipath signals are placed and referred as first, second and third multipaths i.e, $SBn$, $BSn$ and $BBn$. The direct reflection of four different paths and respective reflection has been measured by Eqs. 28-31,

$$\partial_{SSn} = t_{SSn} - t_D \approx \frac{2}{Lc}[n^2h^2 - nh(a + b) + ab]$$

(28)

$$\partial_{SBn} = t_{SBn} - t_D \approx \frac{2}{Lc}[n^2h^2 + nh(b - a)]$$

(29)

$$\partial_{BSn} = t_{BSn} - t_D \approx \frac{2}{Lc}[n^2h^2 + nh(a - b)]$$

(30)

$$\partial_{BBn} \approx \frac{2}{Lc}[(n - 1)^2h^2 + (n - 1)h(a + b) + ab]$$

(31)

here $a$ and $b$ identify the transmitter and receiver height from the ground surface while $L$ indicates the distance between transmitter and receiver. This scattering model shows that if $L$ gets larger, the time of arrival is negligible. The wave motion related metrics i.e., $a$, $b$, and $L$ are changing. The subrogation of the equation has eventually reached at acceptable arrival time in parallel to various paths can be expressed as Eq. 32,
this calculation ratifies the pristine development by the
settlement of the differences in multipath reflection and may
persist until \( L \) remains larger than \( h \).

\[
\delta \frac{\partial}{\partial L} \sim O \left( \frac{n h^2}{c L^2} \right); \quad \delta \frac{\partial}{\partial a} \sim O \left( \frac{nh}{cL} \right); \quad \delta \frac{\partial}{\partial b} \sim O \left( \frac{nh}{cL} \right) \quad (32)
\]

### TABLE 5. Simulation Network parameters.

| Parameters                        | Setting                  |
|-----------------------------------|--------------------------|
| Sensor node area occupied         | 800 m × 800 m × 800 m²   |
| Medium                            | Acoustic                 |
| Nodes quantity                    | 100-400                  |
| Nodes initial energy              | 98 J                     |
| Depth threshold                   | 8 m                      |
| Min: and Max: communication Range | 110 m, 200 m             |
| Packet Size                       | 64 bytes                 |
| Packet generation frequency       | 0.03 pkts/min            |
| Velocity                          | 1500 m/s                 |
| Node displacement                 | 0-4 m/s                  |
| Channel capacity                  | 10 Kbps                  |
| Frequency channel                 | 24 - 28 kHz              |
| Transmission power                | 1.8 W; 0.75 W; 8 mW       |
| Data packet interval              | 48 s                     |
| Channel bitrate                   | 140 b/s                  |
| SNR for Signal Acquisition        | 18 dB                    |
| Number of rounds taken for simulation | 500 rounds             |
| Number of Concentric Circular Rings | 7                      |
| Time for confidence interval conver- | -0.018; 0.038          |
| gence (\( T_f \) -97%)              |                          |
| Distance for confidence interval convergence (\( D_f \) -97%) | -0.014; 0.0277 |

**IV. PERFORMANCE ANALYSIS**

Getting real-time performance for proposed UPRA-PR methodology using NS2 simulator integrated with AquaSim 2.0, both are coded in Octl and C++ mainly designed for acoustic signal attenuation and packet collisions. The performance results of UPRA-PR compare and ratified with DBR, GEDAR, \( H^2 \)DAB, and FBR accordingly. In 3D underwater topological architecture, various sensor nodes from 100 to 400 are deployed at different locations. For this scenario, the maximum and minimum communication distance has been fixed using setdest [55], it’s a command that creates number of hops between the nodes using the GOD (General Operations Director) object and debuts the mobility for node in terms of meters/second.

In the real underwater scenario, the number of nodes used to collect oceanographic data will vary as little depending on the properties of the commercial acoustic modem. When sensor node debuts broadcast packet towards neighboring node follow the procedure defined in respective algorithms for Packet legitimation, Path loss determination, Link selection, Packet forwarding and the Forwarding node impingement (FNI). The simulated result vouches the performance of UPRA-PR for Estimated path failure, Point-to-point delay estimation, System energy consumption, Network operational lifespan, Forwarding node impingement, Network throughput and Multipath propagation Affect in respect to the protocols DBR, GEDAR, \( H^2 \)DAB, and FBR. The simulation parameters are listed in Table 5. Multi-hop environment has been considered and thereby packets are transmitted by considering all hops comply to criteria defined by the system setting.

Each sensor node sequentially broadcasts data packet toward neighboring nodes led by multi-data routes that finally approaches at the sink node. Therefore, transmission could be accomplished if all packets reached at the sink node. When transmission starts, sensor nodes are being generated and follows an arc shape arrangement as shown in Fig.8. The sensor nodes are grouped according to the current depth and transmission power of different zones as depicted in Fig.9. This arrangement was discussed previously in section III accompanied by Fig. 3.
A. ESTIMATED PACKET DISSEMINATION RATIO

The broadcast packets from source node finally received at destination sink node is called packet dissemination ratio therefore, if no packets are received, this means no packets to send. The probability of packets belonging to the UPRA-PR scheme successfully acknowledged by the sink node have evaluated and the packet dissemination ratio was compared with other protocols such as, GEDAR, DBR, H2DAB and FBR illustrated in Fig. 11. The node shifts positions randomly into and out of the transmission zones as well as the specified route and thereby affects the packet dissemination ratio. The overall packet dissemination ratio is increased with increasing number of nodes and thereby more eligible nodes could be able to transmit the packet towards destination sink node. As a result, the packet dissemination ratio of UPRA-PR and rest of the protocols converged with increasing network density. The UPRA-PR appears with higher packet delivery ratio than others due to exclusion of nodes having longer depths (deprecate nodes) than the source node. It also considers the packet reverberation mechanism thereby does not broadcast the same packet again in the line of directional angle towards dearth node. Eventually, sink node achieves an effective packet transmission ratio. As a result, the packet dissemination ratio of UPRA-PR and rest of the protocols converged with increasing network density. The UPRA-PR appears with higher packet delivery ratio than others due to exclusion of nodes having longer depths (deprecate nodes) than the source node. It also considers the packet reverberation mechanism thereby does not broadcast the same packet again in the line of directional angle towards dearth node. Eventually, sink node achieves an effective packet transmission ratio. Comparing to DBR, the data packets are only transmitted around nodes available in deep to shallow water. When such data packet approaches a node, which has no accessibility or inactivity, the packet enters the void area and leads to loss. The horizontal distance on the other hand is not considered even if the packets are sent to the nodes toward upper water surface. These packets might be diverted from actual route and miss the sink node. Thus, the packet dissemination ratio of DBR becomes confined, particularly if the sink nodes are higher. While GEDAR and H2DAB are performed well and almost achieved same dissemination ratio. Further, these protocols do not consider the packet dissemination ratio to be a selection criterion of the forwarding node. Analyzing performance of FBR protocol which possesses a cross-layer architecture that seems unfit and could not perform well as compare to rest of the protocols and forward the packets toward different rout. The forwarding area is transmission dependent and even if the transmission power to be increased significantly to enhance the packet dissemination ratio, this might lead to shortened the lifespan.

B. ESTIMATED PATH FAILURE

Acoustic signal path failure is an inevitable factor during packet transmission. Its probability could, however, be reduced by a placate manner, i.e. decreasing the cross distance. As UPRA-PR avails the thorp propagation technique to rummage and eliminates the ambient noises from transmission routes, thereby only actual signal will travel nearly linear ratified by the result in Fig. 12. This confirms the statement made in the algorithm 2 regarding path failure. While all competing protocols almost have same output in the shape of uncouth transmission, which eventually increased
the routing tangle. The GEDAR protocol could not deal with the void communication issue and therefore faces a large path failure. In case of DBR in a spares network; the path failure exacerbates because the neighboring nodes near to the surface area are priory chosen for next-hop forwarder and the selection of transmitting nodes is not achieved. Therefore, packets are not trapped in the void area but does not have recovery process if getting trapped in a local maxima. The $H^2$DAB can only perform in a stationary sink environment, thus forwarder node selects a node with smaller hop Ids as the next hop node because the nodes with shorter hop Ids are close to the sink node and the entire protocol uses a single forwarder node strategy. Each Hop-forwarding must be carried out in a short-stipulated duration, which is hardly possible and eventually route becomes unavailable. As FBR carries transmission through a virtual pipeline which contains only a portion of the communication zone. If a stable route cannot be established within the specified timeframe, it will widen the transmission zone and each time the chances of a path failure are higher.

C. POINT-TO-POINT DELAY ESTIMATION

An estimated time consumed by a packet from the creation to delivery at the destination node is known as point-to-point delay. The simulation result illustrated in Fig. 13, the initial point-to-point delay for all protocols decreased negligently as the number of nodes increased. This is because each designated forwarder could locate more alternate nodes which possess higher residual energy and moves toward sink only if the network is not sparse. The nodes possess greater energy will lead to the maintain the lowered occupying time, which results in increase the total holding time. UPRA-PR stands at a lower point-delay compared to DBR, $H^2$DBR, FBR and much better than GEDAR because the route selection criteria followed by UPRA-PR depends on ALQ and therefore only shrewd links are taken into account. In addition, the node resides at deeper location and the dearth nodes are also ignored at first transmission round. Eventually, the probability of the packet delaying gets lowered. The $H^2$DAB and FBR protocol came up with similar performance but not the shrewd as compared to the DBR protocol, because the hop count traveled during packet transmission is considered in the DBR protocol. Despite this DBR could not performed well as compare to proposed UPRA-PR, if nodes accidently displaced from transmission zone the packets forwarded to nodes near the water surface can be lost. The delivery ratio of DBR is therefore confined, particularly when there is a limited number of sink nodes. GEDAR appears worst to all because it calculates holding time with two-hop advancement and thereby took too much time while blocking low priority nodes transmission and detecting high priority node sent the same packet.

D. SYSTEM ENERGY CONSUMPTION

The cumulative energy usage by all nodes during entire transmission rounds delivering packets from source to final destination is known as system energy consumption. In all stages, energy consumption statistics are compared and the
FIGURE 14. Evaluation of system-wide energy consumption.

FIGURE 15. Considerable network lifespan during active nodes.

FIGURE 16. Considerable network lifespan during number of transmission rounds.

The performance of proposed UPRA-PR protocol with GEDAR, DBR, H2DBR and FBR are exclusively illustrated in Fig. 14. The proposed UPRA-PR system used far less resources while transmitting packets to the sink node because it selects the forwarding relay node on the basis of the ALQ factor that determines the number of links appeared to be shrewd for forwarding packets. In addition, transmitting same packets toward dearth nodes and the nodes locating at higher depth than the source node is heavily controlled. This eventually saves the exorbitant energy and therefore, packet retention time of each relay node prevents the packet collision. The GEDAR and FBR have utilized higher energy than the other protocols due to a widened transmission radius and keep trying to incorporate additional forwarding nodes; however, the increasing number of routing path will increase the duplicate packets, which leads far worse energy wasting. There are no void prevention measures are available for H2DAB, therefore when approached by 250 nodes, due to void occurrence, the extra energy has been wasted by the void nodes. The GEDAR works much better than the DBR protocol because transmission relay hop count has been taken into account for the surface sink node. The GEDAR ranked the relay nodes according to their residual energy but failed to resolve the packet collision that leads wastage of energy.

E. NETWORK OPERATION LIFESPAN

The amount of time during which entire network remains operational while transmitting and receiving of data packets by the sensor node is referred as network lifespan. According to the result obtained in Fig. 16, The lifespan of the network under the protocols DBR, H2DBR, GEDAR, and FBR is much lower relative to the UPRA-PR. In fact, our proposed protocol leveraged with ALQ factor that chosen the optimal forwarding node with a shrewd link between the source and forwarder node. The chosen communication link was carrying maximum residual energy whereas, the dearth nodes having residual energy less than 20% were hiatus and considered inappropriate for operation. This results a tangle free routing and smooth network operation has been achieved. The estimation for energy consumption has been generated in relation to number of alive nodes. While approaching to 250 nodes, network already has consumed 50% of its resources and other protocols were about to defunct in contracts to the proposed UPRA-PR protocol. The DBR performance seems better to some extent than the rest of protocols because nodes with lower depth were chosen more frequently, but statistics shows this cause a rapid energy exhaustion. For FBR, the transmission orbit has shortened the network lifetime thus, adjusting the depth position of the void nodes eventually consumed extra resources. Facing communication void issue, the H2DAB could not perform well even to DBR and went down without making any significant contribution. In relation to the transmission counts, the network lifespan has been analyzed in Fig. 15, where network activities are closely monitored and an average of 500 simulations were taken into account when more accurate analyzing the network...
operations. However, it is observed that an overarching common trend appears, that is all curves have a decreasing behavior in terms of number of rounds. It is worth noting that nodes start to die faster in FBR than others. The relay node keeps sending data packet until the energy level collapse below the threshold level which imposes a high burden on the relay node as well as on the storage capacity. This results the faster decay of the nodes. On the other hand, UPRA-PR shrewdly adjusts the momentum during transmission rounds and perform the forwarding very accurately. At approximate 400 rounds, the performance of GEDAR begins to get somehow better than FBR protocol, which seems the network might operate longer. DBR shows a better performance than $H^2$DAB and GEDAR where it persists functional for 480 rounds.

**F. FORWARDING NODE IMPINGEMENT**

In fact, this phase is a most belligerent feature of our proposed methodology that has come up after bustle contrives. The impact of forwarding node on battery lifespan after packet transmission has been carefully evaluated for all protocols. The numerous forwarding nodes debauches the batteries lifespan by leaving bleak impact which eventually diminishes the performance cycle. It is crucial to investigate the number and capacity of forwarding nodes that cause this calamity. The proposed algorithm (FNI) renders the shrewd process to evaluate the causing factors and related maleficient activities. The Packet Reverberation is a unique approach that has been used first time to rummage out the impingement of forwarding nodes. We have obtained incredible results which have led to greater control of the energy flooding. At nearby 500 transmissions, maximum 25 forwarding nodes were examined and the packet impingement was handled back by the source node as depicted in Fig. 17. The comparison shows that UPRA-PR has taken into account the maximum dearth nodes and left the sear impact on battery life. Using packet reverberation technique, the same packet re-broadcast to dearth nodes has been hiatus and the energy flow was reduced to an impressive extent. Indeed, this process does not follow by the other protocols. The DBR and $H^2$DAB were unable to cope this forwarding impact and eventually their batteries were drained out by repeating rebroadcast the same packet to the death node again and again. Considering FBR performance, in a dense network while nodes are located far away, an increased transmission range directly affects the throughput and the increasing number of duplicate packet generation could not handle more intensive nodes during the stipulated time. The GEDAR is already facing uncouth energy consumption tribulations, which dramatically exacerbates its performance, and therefore its nodes have died in the past.

**G. NETWORK THROUGHPUT**

The rate at which packet or information successfully sent through the network and acknowledged by the sink node is called network throughput. A throughput and packet dissemination ratio both measure the strength of network and in general, throughput is directly proportional to packet dissemination ratio. When network becomes denser and the number of dearth nodes are increasing, the exorbitant communication load directly hit the performance metrics of the UPRA-PR. In this condition, the selection of shrewd link provided by the ALQ, the proposed mechanism sagaciously controls the generation and the diversion of duplicate packets. Consequently, the routing tangle has been greatly reduced and packets are entering sinking node without barriers, therefore network throughputs touches the peaks as depicted in Fig. 18. The packets transmitted by the DBR seems opposed to other protocols due to a large number of redundant packet generation but the packet’s effective ratio is lowered due to its complex forwarding mechanism. Whereas $H^2$DAB and GEDAR both have identical throughput due to the significant reduction of redundant packets. The ample performance has been seen for FBR, reaching by 350 nodes significantly improved the packet delivery ratio due to extra transmission shells. Thus, source node used extra power metrics communicating directly with the destination node.
V. FINDING DISCOURSE

In order to analyze the performance metrics of proposed UPRA-PR protocol, the results are taken after 500 transmission rounds. Considering packet dissemination ratio, the sum of packets received by the sink node to the total sent was successfully received. This was arisen as the number of participating nodes were substantially increased. Due to the exclusion of higher depth nodes and further taking into account the Reverberation Packet mechanism for dearth nodes the duplicate packets have been ceased meticulously and eventually UPRA-PR achieved significant improvements. It is worth mentioning that packet dissemination ratio and network output are closely intertwined and directly proportional to each other. The network throughput refers to the rate at which packets are transmitted exclusively over the network. If the network is congested and has a reasonable chance of adjustment, the packets may reside in a queue at the source and never attains the network. In fact, these packets do not attach to the output, but never sent to participate, therefore cannot vacillate to packet dissemination ratio at all.

While designing the shrewd underwater routing mechanism, the packet dissemination ratio is more important but for output performance, the network throughput has higher leverage which often remains greater than the packet dissemination ratio due to some ambient noises. In the event of a path failure, UPRA-PR considered the thorp propagation mechanism for rummaging and rejection of the unavoidable noises and allows only litigate packets to minimize the route failure probability. UPRA-PR vouched that it has stringent control over delay factor which has achieved with ALQ route selection criteria and selects only eligible and shrewd communication links. Since the selection of shrewd communication link has been achieved by ALQ and the predefined Threshold Criterion $rc$, nodes in UPRA-PR system consumed trivial energy as compared to the rest of the protocols and ALQ has identified the number of links appeared to be shrewd to forward the packet toward the sink node. Further, the retransmission of same packets to the dearth node and the nodes locating at a higher depth than the source node is heavily controlled. Consequently, significant improvements for network lifespan has been achieved. Most importantly, the pristine contribution of this study is unfolded using forwarding node impingement algorithm (FNI), where shrewd measures are taken into account to control the duplicate packets and rummaged out the impact of the forwarding node to the battery lifespan.

VI. CONCLUSION

Exploring the impingements of forwarding node left on battery life during packet transmission in underwater routing through Packet Reverberation process was never explored before. This challenging task not only revealed the unique research avenue but also significantly improved the use of uncouth energy by the Localization-free, Underwater Pragmatic Routing Approach through Packet Reverberation mechanism (UPRA-PR) in opportunistic routing (OR). Making a significant contribution to the use of confined energy in the underwater acoustic network expands the network topology, forwarding relay node selection and transmission model. All this have achieved by a supportive algorithm. The proposed UPRA-PR mechanism has accomplished the target in four phases. In first phase the packet legitimization has been verified whether belongs to same transmission zone or not through a Node Depth Factor ($N_{D}$), if this factor is found greater than the residual energy of the node, the packet will be accepted and rejected otherwise.

The structuring of the packet forwarding mechanism is in fact, the backbone of the proposed protocol which is carried out in second phase and the formation of relay node selection was established. The path loss ($d_{ij}$, $f$) was computed which determines how many ambient noises are causing hurdles to route creation mechanism and consequently it confirmed that whatever the fading channel may be, the acoustic signal will propagate under any circumstances if the channel fulfills the data rate criteria $D_c$. Proceeding further, the shrewd communication link selection process has been investigated by developing an Accepted Link Quality (ALQ) factor where a predefined Threshold criterion $rc$ determines the quality of the connection, such as shrewd, pristine, fair or uncouth. Only a shrewd link is used broadcast packets.

Most importantly, the impact of the forwarding node left on battery performance has been evaluated. This has been achieved by developing the Forwarding Node Impingement (FNI) algorithm using Packet Reverberation mechanism. Nodes with less than 20% residual energy are unable to participate in transmission and these nodes have previously been used as relay nodes while this time they were called Dearth nodes. The source node hiatus the duplicate packet transmission through the reverberation packet mechanism for dearth nodes, which eventually reduces the energy wastage. Simulation is performed using NS-2 with AquaSim 2.0 and performance of proposed mechanism has been compared with DBR, $H^2$DAB, GEDAR and FBR protocols. The overall outcome has ratified that UPRA-PR performed sagaciously in terms of Packet dissemination ratio, Path failure, Point-to-point delay estimation, System energy consumption, Network operational lifespan, Forwarding node impingement and Network throughput.

VII. FUTURE RESEARCH DIRECTIONS

The problem concerning the impingement of the forwarding node on the longevity of the battery life is still at large. We are working to extend the current finding in diverse positions and mitigate the probability of unavoidable factors effecting to acoustic signal propagation.

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