Design of Shrewd Underwater Routing Synergy using Porous Energy Shells

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ABSTRACT

Underwater sensors link establishment and quality inspection challenges are blurt out during ubiquitous data monitoring. The energy utilization has a direct impact because all active devices are battery dependents and no charging or replacement actions could be made when cost- effective data packet delivery has been set as a benchmark. The hop link inspection and the selection of a Shrewd link through resurrecting link factor was a nothing short of bleak challenge which could only be made possible after going through meticulous research by developing a shrewd underwater routing synergy using extra porous energy shells (SURS-PES) which might never have conducted of before. After broadcasting packets the sensor node conducts a link inspection phase thereby, if any link is found to be less than or equal to 50% shaky; the destination receiving node puts in own residual energy status and return back to the source node which in result adds some unusable energy porous shell to strengthen the link from 50 to 90% at most and send it only to the targeted node and an unaltered data packet delivery is anticipated. Performance evaluation has been carried out using NS2 simulator and obtained results have been compared with DBR and EEDBR to observe the distinguish outcomes thereon results in vouches for the statement that has been made earlier for this research direction.

KEYWORDS

Underwater wireless sensor networks, Shaky links, Ramshackle, Resurrect link factor, end-to-end delay, Network performance

1 Introduction

Underwater ocean environment always remains bewilder and its nothing short of capricious all. No favorable transmission medium like radio and optical signals are well suited in UWSNs because radio waves are prone to highly absorbed in water while attenuation is another fistula. Therefore, acoustic waves are the only best solution. Continue to propagate the signals towards higher distance with low frequencies the radio waves demand huge shape antennas and higher transmission power to operate [1]. While optical signal requires higher precision for pointing the narrow laser beam but scattering makes it vulnerable [2].

Unlike RF signal, encompasses higher attenuation during conductive sea water and optical signal do not suffer by such attenuation but it ever faces the impended scattering issue. There are some hindrances in acoustic signals like bandwidth limitation, increasing rate of bit error and delay count in propagation [3]. UWSN have countless applications particular in oil/ gas exploration, battlefield spying, building inspection, target field imaging, disaster detection and prevention, submarine targeting, offshore and natural undersea resources exploration, detection of atmospheric conditions like change in temperature, light, sound or the existence of unlikely objects and of course the inventory control etc[4]. At the same time bunch of challenges are ahead to face by UWSN. Sensor node are fully battery dependent and it's hard to recharge or replace the batteries in harsh environment [5] whereas, no chance to exploit a solar energy due to rapid dynamic change in water surface. In addition, acoustic signals are subject to transmission over higher distance which engulf a tremendous amount of power compare to terrestrial network. Therefore, only alternate is left to design a shrewd routing path through which data packet might rover from source to destination surface sink node and ultimately forgo the energy depletion. The researchers have been worked out to design the proficient routing mechanism that generate the scrumptious output in this regard and came up with many energy efficient routing protocols.

It's a hard to implement the direct transmission from source node (at bottom) or middle towards surface sink, because this method impends the unconfined energy wastage therefore, researcher adopt the opportunistic routing (OR) based technique which require the flooding makeshift. As each node broadcast the bunch of packets termed as flooding which consume huge energy to locate the routing path. Meanwhile, OR is used to explore the qualified neighboring relay node using factors like end to end delay, packet transmission etc. Though it works fine only in certain condition but not at all, timely require the number of retransmissions which causes high energy lose. A simple cognitive approach is a geographic routing, which do not establish an entire route but consider the location information to send the packet. Similarly, packet is forwarded by each hop node near to the destination. There is a great chance of void occurrence which prone to vandalize the entire strategy.

Underwater routing protocols are categorized into two groups, the location based and location free, indeed. First consider the location based protocol where the GPS plays a vital role as with the help of sink it provides the location information regarding network but big hassle arise when the relevancy of location based routing is reduced by the uneven environment and simultaneity, while location free routing protocols have more potential but it also possess some drawback like network parameters are not much effective to choose the next forwarder node and there is a chance of unsuitable link selection which will consume high energy[6]. While speculating to Depth Based Routing (DBR), ignores the residual energy and consider the depth information for next forwarder only. On the other hand, the proposed Shrewd Underwater Routing Synergy using Porous Energy Shell (SURS-PES) avails the residual energy but do not impact the link factor for next forwarder and it also do not bothered about depth information. Whereas a DBR have greater chances of energy wastage while choosing the regular passage due to shaky links [7].

Underwater nodes when bears low water pressure might die earlier in usual routing scheme. Reckoning the aforementioned crucial challenges, it is essential to contrive a tenable underwater routing methodology that must consume a trivial energy and generates the scrumptious results. Therefore, a Shrewd Underwater Routing Synergy

(SURS-PES) has been proposed that aims to prolong the energy efficient avenue by utilizing Energy Shells. It is a tranquil energy harvesting solution, which operates in three phases considering i.e., (*i*). Resurrect link factor, (*ii*). Depth & residual energy and finally the (*iii*). Packet transmission. A resurrect link factor is a unique concept regarding hop link inspection. After sensing the data when a sensor node broadcasts packets toward neighbours, the hop link factor stimulates the link inspection process as elaborated in figure.1 Flow chart. If link threshold found to be greater or equal to 50% of energy shells, the receiving node acknowledges by add its residual energy information in the received packet and send it back to the source node; upon receiving substantial acknowledge information the source node again sends the duplicate packet only to that node and this time the duplicate packet possessed the extra energy shell which strengthens the link quality from 50% to 90% at most. Henceforth, a successful packet delivery will be carried out thereupon, relay node formation is prone to complete. The complete methodology has been discussed in the methodology section. This concept of resurrect link factor has not been investigated yet in other research ground.

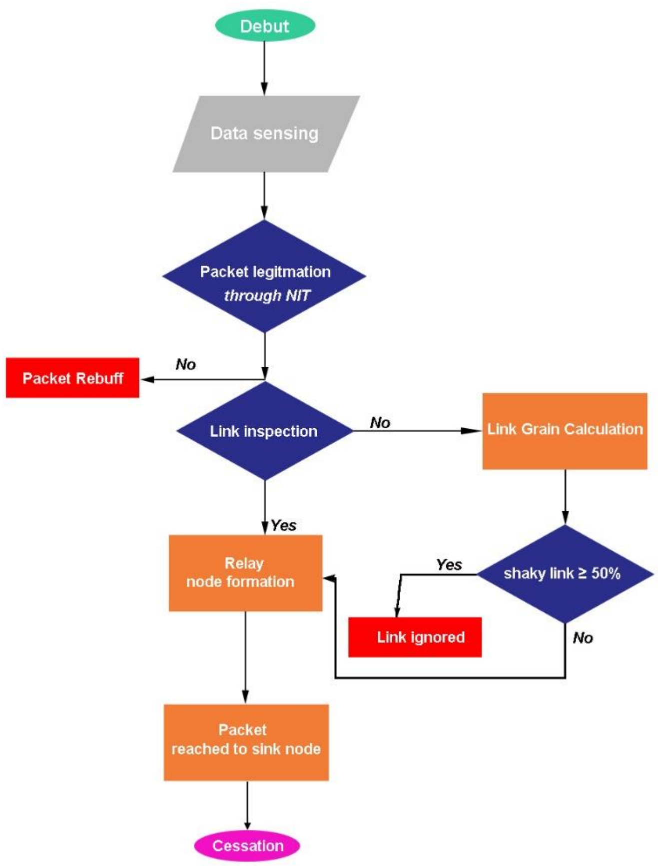

Figure 1: Proposed (SURS-PES) methodology flow chart

Rest of the discussion are arranged as; section 2 highlights the related work. Section 3 covers the details of suggested (SURS-PES) routing methodology. The performance evaluation using simulation results have been discussed in section 4. Overall conclusion has been summarized in Section 5 while future research direction is being proposed in Section 6.

2 Related Work

Acoustic communication is the only tranquil solution for underwater data routing due its unique channel feature [8]. For terrestrial communication the radio and electromagnetic waves are the best media because these cover a wide range of distance but in-case of underwater totally fails, therefor the acoustic signals plays the scrumptious role in such environment despite of limited bandwidth and the propagation speed which is about 1500 m/s consider as very slow[9]. Nodes bearing low water pressure die early in the usual routing approach.

The acoustic signal debuts propagation process through unique medium as contrast to radio frequency. Although there are some obnoxious factors that causes to energy drainage at large. The acoustic signal reflects, scatter and observed by the seabed and water surface, due to which transmission data losses. The submerged acoustics operates between 10 Hz to 1 MHz frequencies. Due to a confined acoustic spectrum, only limited range of frequencies are usable in underwater communication. [10]. The unavoidable factors like salinity, temperature and water depth merely, effect the speed of acoustic signal therefor, acoustic wave spreads into a curved path and sensor node can't overhear the signals. As a result, void area is prone to create out and nodes in this area can't participate in transmission process which eventually shorten the network lifespan.

Recharging or replacement of batteries is not an easy task in underwater ocean specially in harsh environment therefor, it is essential to design an efficient data routing protocol that could explore and maintain the routing path either from bottom to the ocean surface in order to deliver the data packet according to the desired level with limited energy power. While designing such energy efficient underwater routing protocol, there are some uncouth challenges like, bandwidth is distant dependent and in case of long-range transmission, it presages a high energy utilization and even transmission path losses to. There possesses a higher propagation delay because speed of acoustic signal in underwater is very low [11]. Although there are many routing protocols available that claims to be energy efficient but every time requires a specific routing path during transmission; infact these are expensive and consume exorbitant energy [12]. Most of the routing approaches don't consider the link quality therefor, retransmission with hollow links are energy wasted. The performance attributes of relevant underwater opportunistic routing (OR) protocols are being analyzed according to the class structure as

2.1 Location based Opportunistic Routing

Based on location information of sensor nodes, OR creates an imaginary virtual 3D-pipe from relay to sink node to avoid the Forwarder Set Selection (FSR) issue. *Costantino, G et al* [13] proposed a depth-based routing (DBR) for underwater communication. The packet routes from sensor to sink through greedy technique with better data packet delivery but it engulfs a huge energy and high end to end delay is recorded even no prevention measures are suggested.

A directional packet flooding is adopted by *Ahmed, S et al* [14], as a Directional flooding-based routing protocol (DFR) each node is award of its own location with single hop neighbours' location and position of sink node is also recorded. In order to forward a packet, the link quality determines the flooding zone between source to sink node. Although this method results out a pristine packet delivery ratio with trivial overhead but no measures are given to address the void occurrence and it is not suitable in parse environment.

Vijayalakshmi, P et al [15] developed a Vector based Forwarding (VBF) a stateless routing protocol the packet routes between source and sink node along a redundant and interleaved path therefor, only few nodes participate in forwarding process. The redundant paths are maintained by a self-adaptive algorithm and nodes freely chooses the best path to forward the packet. When destination node receives the packet, it computes its relative position and records the distance from forwarder with angle of arrival (AOA) adjacent to the vector. Despite of robustness to the packet loss and node failure, it is only suitable for a small network but becomes uncouth in multisink environment.

Khasawneh, A et al[16] proposed a pressure based location free underwater routing protocol mainly takes into account the link quality, depth information and residual energy. Author has utilized the triangle method to investigate the link quality and developed a multi-metric data forwarding algorithm to calculate the route cost. This method is only suitable for trivial networks and do not offer void handling technique.

A cross layer design issue has been worked out by *Yan Chu et al* [17], aims to lower down the energy consumption and prolong the network lifetime. The factors like, link schedule, transmission power and transmission rates are carried out with time division multiple access. An optimization issue is handled using interactive algorithm in linear and rhombus topologies. It seems that due to sudden displacement of nodes, scheduling becomes out of order and algorithm do not present such activity and becomes futile in nature.

2.2 Location Free Opportunistic

Routing: Based on number of hop-counts using dynamic address and pressure information the suburb nodes are being identified. The sink node timely generates the beacon messages and which travels from water surface towards inner depth with a unique identification called dynamic address. Different beacon-based protocols are used for different network topologies all with varies information like addresses, assigned to the sensor nodes. As Location Free OR uses the topology information to find the forwarding rely nodes. To get rid of FSR, for *2H-ACK*[18] protocol, each node is bound with a dynamic address like a beacon message, the neighboring node having smaller address and closer to the sink shall be ranked as well the member of forwarding set nodes and node with smallest address shall be selected as next hop node. To tackle the DFS issue in the presence of unreliable links, it considers only single next forwarder node which is not a placate method.

Ashraf, S et al [19] proposed a lower power listening (LPL) mechanism to monitor the faulty nodes and energy wastage through ContikiMAC Cooja in UWSN. The energy consumption is reduced in centralized and distribute approaches. The author has figured out the energy consumption with end to end delay by proposing a stochastic model for UWSN, however the model considers cylindrical propagation but lack of common spherical.

While *ERP*^{2}*R*[20] assigned a perpendicular distance from the pressure-based OR protocols like DBR and HydroCast deals the FSR, CV and DFS issue wisely. In forwarding set a lower ranked node listens what packets are going to forward by the higher ranked node, the packet shall be removed from the queue or in other case after the completion of holding time of a packet it will forward the data packet. Regarding CV issue DBR couldn't have any suitable solution yet.

Data packets are forwarded from node to node in a store and forward fashion with *Hop-by-Hop Dynamic Addressing Based (H2-DAB)*[21] where every sensor node is packed with hope-ID address and broadcasting Hello packets are received by the forwarder and every receiving node accepts this Hello packet including the hope ID. Smaller hope ID are assigned to those nodes having nearby existence to sink node, just because of hope ID gets incremented. As a result, hope-by-hope protocol puts in only those nodes which have lower hope ID for packet forwarding.

Among location free routing series, void problem has been solved by *Barbeau, M et al* [22] with Location Free Link State Routing (LFLSR). Selection of next forwarding hope node depends on three factors; (*i*). the hope count, (*ii*). route and (*iii*). depth status. Route from sink to source node is handled by a beacon message that updates the route information. It requires a higher power consumption while using the pressure device to measure the path.

3 Proposed Methodology

A meticulous study has been conducted out for a robust and energy efficient underwater mechanism which unveiled the idea of a Shrewd Underwater Routing Synergy by utilizing the Porous Energy Shells (SURS-PES). The selection of a shrewd link quality and packet forwarding mechanism has been investigated and relay node formation is being explored.

3.1 Operational Model

The proposed network architecture (SURS-PES) has been shown in figure. 1 mainly contains, sensor nodes deployed at varying depth positions; a sink node is located at upper water surface while offshore base-station is available out

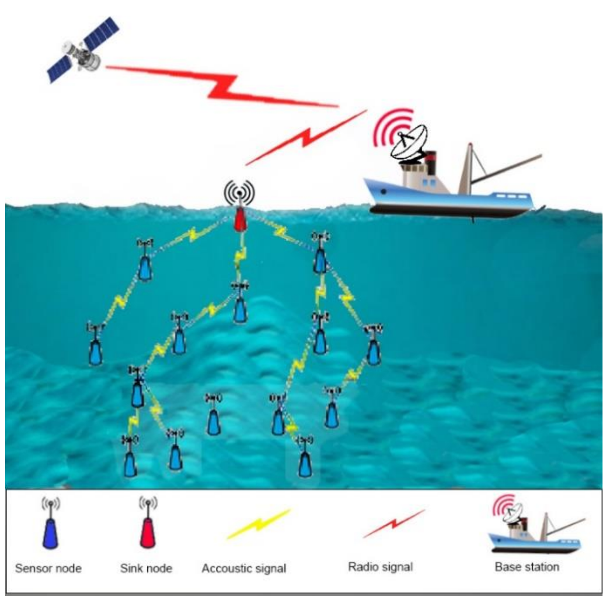

Figure 2: Modular topology

of water. Sink node receives data packet from source and neighboring relay nodes as well. It is packed with acoustic and RF model. The acoustic modem pertains to communicate with underwater deployed sensor nodes whereas, RF modem devolves for sending information to the base station. A successful data packet reaches at surface sink through hop-by-hop routing rovers thereby intermediate neighboring relay nodes. Every node obtains its depth information through depth sensor while residual energy is recorded through distributed beaconing.

At receiving node, the distance from neighboring relay node is being ratified through *Received Signal Strength* (*RSS*) [23]. Signal attenuation depends on spreading loss which can be determine by the Thorp Formula. For a particular frequency *f*, and absorption loss α(*f*) is expressed in Eq. (1).

$$10\log\big(\alpha(f)\big) = \begin{cases} \frac{0.11f^2}{1+f^2} + \frac{44f^2}{(4100+f)} + 2.75\ X\ 104f^2 + 0.003, & f \geq 0.4 \\ 0.002 + 0.11\left(\frac{f}{(1+f)}\right) + 0.011f, & f < 0.4 \end{cases} \tag{1}$$

here α(f) is rated in dB=km while f is the frequency in kHz and α is equal to the absorption loss as $\alpha = \frac{10^{\alpha(f)}}{10}$. The attenuation A(1,*f*) is obtained by the cumulative loss whereas spreading is given in Eq.(2).

$$10\log\big(A(l,f)\big) = k \text{ x } 10\log l + l \text{ x } 10\log\left(\alpha(f)\right) \tag{2}$$

where *k* x *logl* is a spreading loss with distance *l* while *l* x 10 *log*(α(*f*)) indicates the absorption loss and coefficient *k* depicts the signal propagation geometry.

3.2 Link Factor

The energy consumption, data delivery ratio and network throughput depend on link stability. The use of *ETX* based protocol infact measures the link quality in the course of forwarding process. These protocols may utilize certain location information from GPS or inquire the finite information from sink node. While proposed (SURS-PES) methodology determines the link quality by taking all measures at the best. Although some other link measuring techniques are in practice like *ETX*, WMEWMA and RNP, where delivery ratio (PRP) is considered to obtain the link quality factor but no success to grab a pristine link have been achieved yet. A pristine link factor can be calculated step wise as

Step 1. LFI & SNR computation

Let *n* be the absolute transmitted data packet while m, *i* are the receiving packets obtained by computing *lfi* and *snri*. Getting *lfi* and snr mean, ratifies that greater LFI and SNR value leads to revitalize the link factor.

Step 2. LFI and SNR mean computation

An overall mean suffers from unavoidable limitations. It cannot handle the packet loss indeed but keeping tracks of the received nodes. adding a priority metric either from (0,0) to ($\overline{SNR}$,$\overline{LFI}$ adjust the link factor. Based on *lfii* , *snri* and PRR, the mean ($\overline{SNR}$,$\overline{LFI}$) have been calculated by PRR metric and forgo the statistical mean. The final values are obtained as Eq.(3,4)

$$\overline{SNR}_w = \frac{\sum_{k=1}^{m} snr_k}{n} \tag{3}$$

$$\overline{LFI}_w = \frac{\sum_{k=1}^{m} lfi_k}{n} \tag{4}$$

Step 3. Distance measurement

A link factor is determined by computing the path $d\Delta$ from origin state (0,0) to point ($\overline{SNR}$,$\overline{LFI}$) thereby Eq.(5) forms as

$$d\Delta = \sqrt{\overline{SNR}_w{}^2 - \overline{LFI}_w{}^2} \tag{5}$$

Step 3. Best Path

Although, longest path between source and neighboring nods $d\Delta$ presages as a best link quality but not a qualified pristine link. A pre-defined threshold *th* value could distinguish the link factor among all as expressed in Eq.(6).

$$\Psi = \begin{cases} Shrewd\ link, & th_{shrewd} < d\Delta \\ Pristine\ link, & th_{pristine} \geq d\Delta < th_{shrewd} \\ Fair\ link, & th_{fair} \geq d\Delta < th_{pristine} \\ Uncouth\ link, & d\Delta < th_{uncouth} \end{cases} \tag{6}$$

while proposed (SURS-PES) mechanism is based on Triangle Matric (TM) thereby, link quality is determined between source and neighboring node and maintains a Link Repository Table(LRT). The threshold parameters upon which link factor is determined are shown herewith in Table 1.

Table 1 Types of link and threshold value

Metric type	SNR	LFI	PRR	Triangle
Shrewd link	>30	>106	1	>145
Pristine link	15-30	102-106	0.75-1	80-145
Fair link	5-15	80-102	0.35-0.75	30-80
Uncouth link	0-5	0-80	0-0.35	0-30

3.3 Information Gathering Cycle

Every sensor node fetches information from surrounding nodes located at lesser depth than its own and thereby sends a HELLO message containing ID, depth and residual energy within transmission range. Upon receiving this message, every nod follows a stipulated sequence and archive the information in Neighboring Information Table (NIT) to ratify the eligibility of the message and accepted if depth is lesser, otherwise rebuff it.

TM first analyses the link quality by computing the accumulated SNR, LFI and PRR values. The estimation process debuts as the sensor node broadcasts a probe packet containing ID, SNR and LFI values thereon. In next phase, PRR generates mean values while a link quality is estimated by calculating the distance based on TM values. The final round updates the NIT table by entering individual nodes' distance, whereas a priority rank is set for a higher distance node. Algorithm1 vouches the information retrieving sequence and flow of information is explained in steps.

Algorithm1: Information retrieving

```
Procedure CreateHello(nodea)
    if HelloLatency is vanished then
    Create Hellopacket
    Include id, depth, and residual energy in HelloPacket
    Broadcast (HelloPacket)
    Set NewInterval
    end if
    end procedure

    Procedure GetHello(nodea, HelloPacket)
    if |nodea.depth|>|HelloPacket.depth| then
    if HelloPacket id is invalid in nodea.NIT then
    Include HelloPacket information to nodea.NIT
    else
            update information in nodea.NIT
            endif
            goto link factor triangle metric(nodea)
            else
                    rebuff(HelloPacket)
                    end if
                    end procedure
```

Step1: Each sensor node (nodea) creates a HELLO message (CreateHELLO) and sends towards neighboring nodes.

Step2: All neighboring node receives (GetHELLOW) message and performs the necessary actions.

Step3: NIT table continuously updates the nodes' information because of periodic changes in the positions.

3.4 Packet Forwarding and Route Cost

Data packets puts forward from source to destination sink node. Though, all nodes actively take part in packet forwarding process but a higher packet delivery ratio can only be achieved when next forwarding node lies nearby a destination sink node having scrumptious link and greater residual energy. Despite, *Wahid, A* [24] computed a diminish cost that hangs on residual energy and *ETX*. However, we put forth the residual energy to determine the route cost and thereupon calculates the TM based distance. Henceforth, the route cost between two nodes *i.e.* (*x*,*y*) is evaluated thereon Eq.(7).

$$Route\ Cost(x,y) = \left(1 - \frac{Res_y}{Res_{max}}\right) + \left(1 - \frac{\Delta d_{(x,y)}}{\Delta d_{max}}\right) \tag{7}$$

The residual energy of node *y* is being represented by Res_y , while Res_{max} depicts the entire nodes' energy, whereas Δd_{max} is an environment specified system parameter. The link quality parameters between sender and forwarder node has been obtained as $\Delta d_{(x,y)}$. Taking two different metrics into an account *i.e.* residual energy and link quality; Eq.(7) is used to evaluate the route cost of the proposed scheme. From this equation it is observed that to keep the route cost minimum, the node must have lower depth than the sender node and results the shrewd link quality. Proceeding to select the next

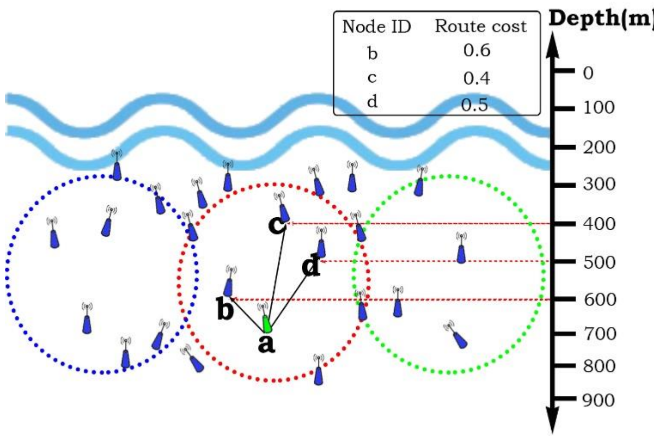

Figure 3: Relay node selection process

forwarding relay node as depicted in figure.3, the sender node *a* initially inquires the information of nearby nodes from NIT. In next phase, it calculates the route cost with Eq. (7). The node possessed lower route cost is selected, here in this case the selected node is *c*.

The sender node *a* encapsulates its ID into data packet and broadcast it towards next hop neighbors. At receiving node, the packet ID is matched with receiving node's ID and if it found valid the packet will be accepted otherwise it rebuffs the packet. By repeating same procedure, finally data packet will be reach at the destination sink node. Due to an uncouth UWSNs the data packet might encounter some hindrance when revering towards final destination [25] the packet passes through different regions and may loss at any location.

3.5 Link Grain Calculation

The proposed idea computes and maintain the link quality more scrumptiously and thereby enhance the concept of link reparation. When sensor node a broadcast the packet p with substantial information like depth, ID and residual energy towards neighbouring nodes *i.e.*, *b*, *c* and d as illustrated in figure 4.

For instance, a source node Na_p is broadcasting the packet towards neighbours, upon receiving this packet node *b* includes necessary information and send it back as $Nb_{p'}$ to node *a*. After adding required energy shells and making duplicate node *a* again multicasts the packet only to node b as Na_{2p} within a trivial time *t*. The final Link Grain is being calculated as expressed in Eq.(8).

$$Link\ Grain = Na_p + Nb_{p'} + Na_{2p} \tag{8}$$

finally the link quality is being optimized with energy consumption Ea_p, $Eb_{p\prime}$ and Ea_{2p} respectively which remains unaltered, thereon Eq.(9) in the due course updates the link status probability from 50 to a 90%.

$$Link\ Grain = t(\sum_{p=1}^{Na_p} Ea_p + \sum_{p\prime=1}^{Nb_{p\prime}} Eb_{p\prime} + \sum_{2p=1}^{Na_{2p}} Ea_{2p}) \quad (9)$$

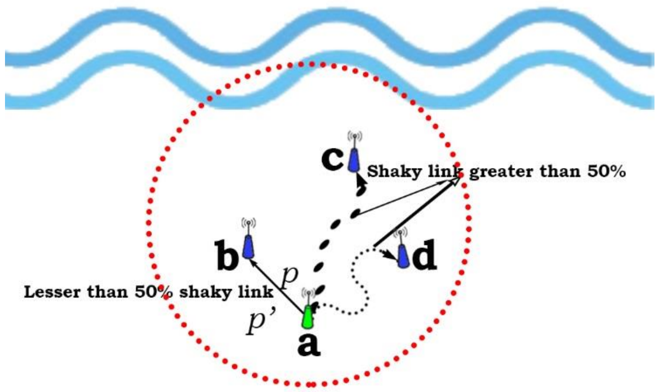

Figure 4: Link Grain determination

Communication links between node a and others are being analyzed meticulously. Thereon, a stipulated link quality inspection is carried out which reports about which hop links are more than 50% ramshackle and what links are more stable than 50% at all. Like link quality between source node *a* and *b* is more than 50% stable but not up to 90%, while links between node *a* to *c* and to d are more than 50% unstable. Therefore, proposed methodology (SURS-PES) takes into account the hop link between node *a* and *b* to make it more stable *i.e*. up to 90% for a smooth packet transmission. Continuing to receiving packet *p* by node the *b* adds the acknowledgment packet and residual energy information and thereby send the packet *p'* back to node *a*. Upon receiving the packet *p'* by node a analyze the position and status of node *b* and adds the extra energy shells to strengthens the link quality and finally transmit the same packet in the form of duplication only to node *b*.

At this point our proposed idea is more viable which utilizes a sender cognitive technique *i.e*. continuously overhears the forwarders' packet and maintains a time dependent corpus. It retains packet in the corpus; when receiving node overhears same packet, the packet already stored in repository is removed out and thereupon, avoids the retransmission fistula.

4. Performance Evaluation

The performance of proposed methodology has been meticulously evaluated comparing with DBR and EEDBR protocols using NS2 simulator and encompasses Aqua-Sim with. For this evaluation 100 to 400 sensor nodes are considered in the network about 1000 x 1000 x 900m3 with a fixed distance of 100m between every sensor couplet as illustrated in figure 3. The rest of the simulation parameters are given in Table 2. When simulation debuts the

Table 2: Simulation setup parameters

Parameter	Value
Deployment area	1000 x 1000 x 900 m3
Distance among sensor couplet	100 m
No. of nodes	[100 – 600]
Communication range	250 m
Type of protocol	SMAC
Start energy	100 J
Medium	Acoustic Waves
Bandwidth capacity	10 Kbps
Packet generation rate	0.02 pkts/min
Velocity	1500 m/s
Node movement	0 - 3 m/s
Energy consumption	2 w; 0:75 w; 8 mw
Data packet volume	64 bytes
Data packet interval (Hello)	99 s
Packet creation time	15 s
No. of runs	50

operation, during Hellopackets interval *i.e. 99s*, the neighboring nodes overhear the depth and residual energy, thereupon distance based TM is computed and while keeping energy model [26] as a base instance, estimates the residual energy and energy consumption as well. After completing *99* transmissions we considered only half of thereof and build the results.

4.1 Point-to-Point Impediment

An entire or thereabout duration by which packet rovers from source through various regions and get accepted at final destination is known as point-to-point impediment. Sometimes unavoidable impediments from transmission, propagation and signal processing are added unintentionally which slows down the packet transmission. Point-to-point impediment can be determined well by the Eq.(10).

$$Point\ to\ point\ Impediment = \frac{\sum_{l=1}^{50}\sum_{m=1}^{PC}(BT_{l,m} - AT_{l,m})}{PC\ X50} \tag{10}$$

The entire packet series when acknowledges at final destination are identified as *PC*. During l^{th} simulation $BT_{l,m}$ indicates the broadcast time of m^{th} packet. Similarly at destination point $AT_{l,m}$ represents the acknowledge time of m^{th} packet during same simulation. In underwater routing, packet holding time mostly causes the point-to-point impediment which has been avoided in the course of proposed SURS-PES scheme. The simulation result figure.5 ratifies that this delay is foremost lower than the rival protocols. It also vouches that such condition remains same for sparse and dense environment, despite even countless computations occurs during the transmission process. Packet holding time and depth information dependency, creates a big hassle for DBR not to perfume well as compare to proposed scheme SURS-PES. Furthermore, a trivial point-to-point delay in contrast to DBR is being observed for EEDBR, because it utilized a residual energy-based packet holding mechanism but if a sudden packet loss occurs the packet holding duration will also increase thereof, might causes an indefinite delay.

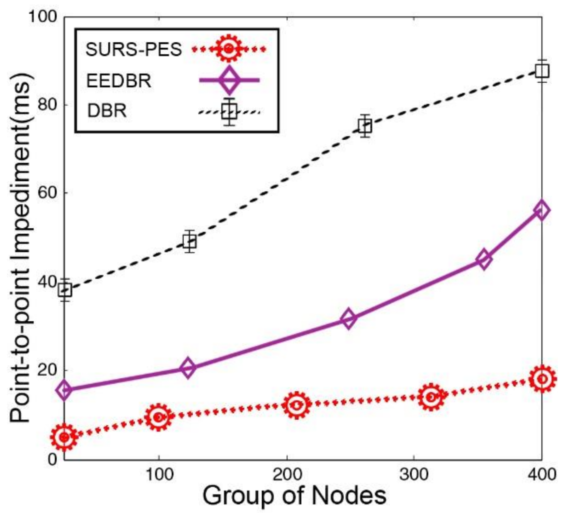

Figure 5: Point to point impediment observations

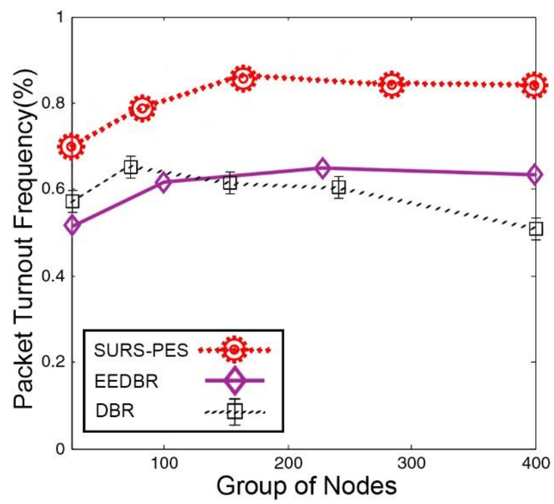

Figure 6: Packet delivery rate

4.2 Packet turnout frequency

A numerical relation of broadcasted packets, when received at final destination *i.e,* sink node in any form or quantity is known as a packet turnout frequency. Primarily this relation (PTF) is expressed in percentage as stated in Eq.(11). During nth simulation, PB and PR stipulates

$$PTF\% \quad = \quad \left\{ \left(\sum_{n=1}^{50} \frac{PB}{PR}\right) \Big/ 50 \right\} \ x\,100 \tag{11}$$

the broadcasted and received packet ratio. Adding substantial nodes can result a shrewd packet turnout. Though, DBR is best fitted on this statement and sufficient packet delivery improvement is seen but a packet holding time adds extra forwarding which might increase a packet collision if network changes state *i.e,* sparse to dense thereby. The unprecedented packet delivery frequency from SURS-PES made possible in the course of astute link selection and higher residual energy. According to figure.6, at near about 160 nodes the proposed scheme achieved better delivery ratio than DBR and EEDBR about 12 and 18% respectively. While at the end of transmission when number of nodes reached to 500 the SURS-PES came up with unbeatable score which is 22 and 12% compare to DBR and EEDBR at most.

4.3 Network Lifespan

The optimal duration thereby sensor nodes actively send and receive the packets is known as lifespan of the system. In order to achieve lifespan more longer, two approaches are in practice *i.e.,* schedule based and range-based approach. For proposed SURS-PES method, a schedule-based approach is been utilized setting to S-MAC protocol [27,28] in simulation result.   An entire network lifespan encompasses the time from first packet being broadcast unless the last packet acknowledged by the destination node and thereupon network puts out. Eq. (12) thereby being manifest to compute the network lifespan.

for a l^{th} simulation, network triggers at NNT_l times and thereby halts at NHT_l time. Statistics shows that if group of

$$Network\ Lifespan = \frac{\sum_{l=1}^{50}(NNT_l - NHT_l)}{50} \tag{12}$$

nodes and field area increases simultaneously, ultimately network lifespan becomes trivial, but if sensor nodes could adjust transmission power among various levels shrewdly thereof distribute the packet load among all nodes by the S-MAC activity thereupon, network lifespan can be revitalized farther.

Continuation to this, the SURS-PES has outperformed as compare to its rivals *i.e.* DBR and EEDBR illustrated in

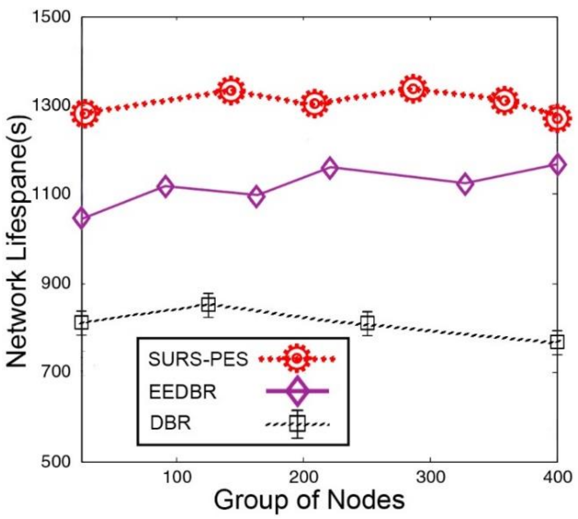

Figure 7: Network Lifespans

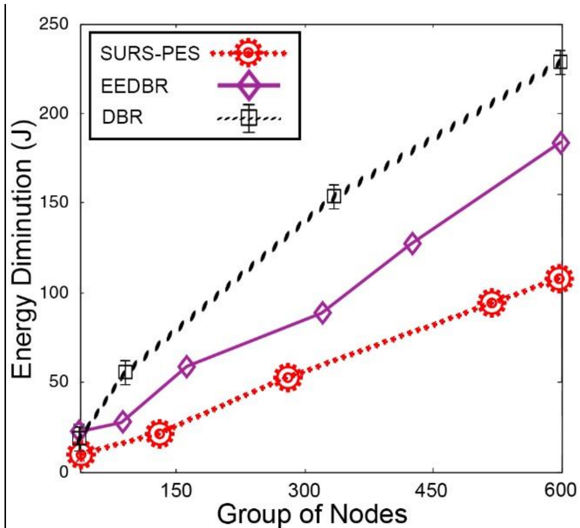

Figure 8: Energy Diminution analysis

figure.7. The higher residual energy with shrewd link factor made possible to extend the network lifespan during forwarding process for SURS-PES Furthermore, proposed scheme do not carry any packet holding tangle thereby, no redundant packet transmission can be impediment to the smooth going transmission no matter how often the network volume becomes dense or sparse. Therefore, network achieves stability that leads to prolong the lifespan indeed. Analyzing DBR performance, indeed its lifespan remained shorter throughout the transmission led to not availing the residual energy except the depth information which is being used for forwarding node selection process only. In addition, the nodes residing at shallow water cannot exists for longer time and may die quickly thereby leads to a network collapse. EEDBR has performed with a deft touch as compare to DBR because the shrewd usage of residual energy and depth information made it worthwhile thereof, only confined number of nodes could participate in packet forwarding hence, no more redundant packets in the results. Despite all, EEDBR performance couldn't approached even near to the proposed SURS-PES scheme.

4.4 Energy Diminution

It is an average energy utilization during transmission round by the all nodes to deliver packets at destination sink node. Eq. (13) put across in determination of energy utilization by each sensor node. Therefore, a node consumes E_x energy thereof transmits a p-bits as a beacon message over distance d, henceforth

$$E_x(p,d) = \begin{cases} p.E_{ds} + p.E_{fs.d^2} \\ p.E_{ds} + p.E_{mp.d^4} \end{cases} \quad (13)$$

where $p.E_{ds}$ is a signal dissipation and $p.E_{fs}$ shows a free space while multipath has been indicated through $p.E_{mp}$. A p bits energy packet is being received by the sensor node thereby it engulfs E_e amount of energy depicted in Eq. 14.

$$E_p(p) = p.E_{ds} \quad (14)$$

when forwarder relay node sends p-bits packet towards destination sink node thereby, consumes $Ef(p,d)$ energy ratifies in Eq.15.

$$E_f(p,d) = p.E_{ds} + p.E_{fs} = \begin{cases} 2p.E_{ds} + p.E_{fs.d^2} \\ 2p.E_{ds} + p.E_{mp.d^4} \end{cases} \quad (15)$$

where E_f is an energy to be consumed during packet forwarding by the sensor node. Summarizing for energy steps, the final and a pristine output has been unveiled through Eq.16 which explicitly exhibits the amount of energy being consumed during packet forwarding by the sensor nodes up to the destination sink node.

$$E_f(p,d) = p.E_{ds} + p.E_{fs} \quad (16)$$

In continuation to performance the proposed SUR-PES methodology has come up with scrumptious energy consumption results illustrated in figure.8. It consumed only a trivial energy during entire period as compared to DBR and EEDBR. No doubt this scrumptious performance has only being achieved due to the impediment of redundant packet transmission. In addition, the smart aspects of residual energy and link quality have been availed to make usage of energy at a confine most. Although, this technique is not useful at every stage thereon, SURS-PES initially faced this situation and thereby, an energy consumption frequency was slightly higher but sooner forwarder node made adjustment and overall consumption had reached to an acceptable level. At near about 290 to 600 nodes the energy consumption ratio becomes liner which indicates that routes are smooth and packet loss is almost negligible therefor, all packets are revering to sink node without wasting extra energy shells. The output enumerates about 27 and 32% less energy consumed than EEDBR and DBR which is a foremost achievement in this situation.

Though, EEDBR performed much better than DBR and could balance the energy utilization by availing all factors *i.e.,* residual energy, depth information and avoiding redundant transmission but failed to deal with increasing quantity of nodes, consequently energy consumption put it at higher risk to die soon. While analyzing the DBR performance, apparently energy consumption has been recorder at peaks, because of no usage of residual energy and with redundant packet transmission it seems vulnerable for rest of the protocols.

5. Conclusion

For underwater routing only shrewd protocols can make the network long-lasting thereupon, role of batteries is very crucial, as entire transmission is battery dependent and if shrewd protocols could make judicious usage of limited battery volume then expected results are achieved. The proposed SURS-PES methodology did the same job as it was being expected at the design time. Applying resurrect link ability with residual energy and depth information made it possible in selection of next forwarding node more scrumptiously as compared to other traditional approaches. Therefore, comprehensive results are obtained in terms of Point-to-Point Impediment, Packet turnout frequency, Network Lifespan and Energy Diminution which were never expected through traditional routing schemes. Revitalizing the link quality thorough Link Grain Calculation is a unique idea that takes into account the link status among source to neighbouring nodes and scrutinize the link qualities as ramshackle less than 50% and greater than 50% separately. When a link is equal or less than 50% shaky a source node adds extra energy shell by considering the residual energy of the targeted node and makes the link up to 90% shrewd thereon packet becomes duplicate and stabilize link for smooth delivery.

6. Future Directions

The future study anticipates with smart exploitation of the artificial intelligence to enhance the UWSNs bandwidth utilization by segment allotment technique which intends to maintain the sustainable network in the line of ubiquitous monitoring.

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