Survey on Depth-Based RoutingVariantsfor Underwater Wireless Sensor Networks

[1]B. Umarani, [2]A. R. Naseer
[1]Department of Computer Science and Engineering, JITS Karimnagar affiliated to JNTUH, India
[2]School of Computer and Information Engineering, INHA University Korea and Tashkent

Abstract: Recent studies in underwater wireless sensor networks (UWSNs) haveattracted the attention of researchers in academia and industry in critical application areas such as catastrophe andearthquake prediction, water high-quality and environment monitoring, leakage and mine detection,army surveillance and underwater navigation. However, the aquatic medium is related tosome of the limitations and demanding situations: lengthy multipath put-off, high interference and noise, harshsurroundings, low bandwidth and restricted battery life of the sensor nodes. These challenges demandresearch techniques and techniques to conquer in an efficient and effective style. The designof efficient and robust routing protocols for UWSNs is one of the promising answers to address those demanding situations. This paper provides a survey on the Variants of Depth-Based routing protocols for UWSNs. These addressed routing protocols fall under the taxonomy of localization-free protocols. These approaches are in addition subdivided in step with the problems they deal with or the majorparameters they employ at some point of routing. In addition, every protocol is described in phrasesof its routing strategy and the problem it addresses and solves. The advantages and limitations of protocols arehighlighted. The description of the routingapproach of each protocol makes its routing operation effortlessly understandable. The demeritsof a protocol present perception into overcoming its flaws infuture investigation. These may result in the foundation of new protocols which can be extra smart, strong and novel withthe preferred parameters recognized.

Keywords: Underwater wireless sensor networks (UWSNs), UWSN challenges, Depth-based Routing variants, Energy balancing, Network Lifetime

I INTRODUCTION

Initially, Wireless Sensor Networks(WSN)covered most effective terrestrial programs, butwe recognize that the Earth is a water planet as greater than 70 % of thefloor is included by means of the water and the large unexploredvastness of the oceans has attracted human's interest. From manya long time, there had been sizable interests in monitoringaquatic environments for scientific, commercial exploration and aswell as for navy operations. A rather specific, actual time andcontinuous tracking structures are extremely crucial fordiverse programs, including off-shore oil fields monitoring,pollutants detection, and oceanographic information collection. Hence allthese critical applications call for the need of buildingUnderwater Wireless Sensor Networks (UWSN).The traditional techniques for the underwater tracking have several drawbacks. Firstly, there have been no help for the interactive Communications between the specific ends. Secondly, in most of the instances the recorded statistics can be retrieved at the end of the mission, and it may take several months, and any failure during the project can result in the loss of all the gathered records. Further, the idea of an ad hoc and sensor networks for underwater may be very attractive, because it is found to be useful without problems to increase the range of current acoustic modems and provide distributed communications with much less deployment time. A scalable UWSN offers a promising solution for discovering effectively and for monitoring the aqueous environments for specific applications, which operate under the various vital constraints. At one aspect, those environments are not viable for human presence as the unpredictable underwater activities, excessive water pressure and considerable vastness of water areas are main motives for un-manned exploration. At the same time, localized exploration is better than remote sensing because of the more precise consequences, as remote sensing technology may not be able to locate appropriate information about the activities happening inside the unstable underwater surroundings. Radio waves can travel for longer distances but because of salty characteristics of water, it really works at very low frequencies, and these low frequencies require massive antenna in addition to high energy for communications. For example, experiments carried out at University of Southern California, indicates that, simplest 1.2m communication range was possible at the high frequency of 433 MHz [6]. On the other hand, optical waves do not have the trouble of any such high attenuation, but suffer from the scattering, and require high precision of the pointing beam as well.

The WSNs framed with sensors are capable of reading, handling, collecting, storing and transforming information to other sensor nodes in unidirectional or multidirectional domains. There are five types of WSNs used for monitoring the environment on the earth, above and below the earth with the data from the sensor nodes. They are Terrestrial, Underground, Underwater, Multimedia and Mobile WSNs. Large numbers of underwater acoustic sensor nodes are clustered in underwater wireless sensor network (UWSN). UWSNs are positioned in an undersea or marine environment and nearby surroundings inundated wrecks, for oceanographic data gathering and calamity prevention [1], [2]. In UWSN, the sensor nodes are integrated in a network to gather information and pass on to the sink node.Fig.1.1shows such a scenario of Underwater wireless sensor networksand Fig.1.2 depicts the components of a typical sensor node architecture in UWSN. In general, UWSN differs from normal sensor networks interms of acoustic signal, cost, memory space, data size, energy and deployment. Mainly the UWSN protocols were used to monitor the areas and collect the information from the various water sources such as streams, canals, pools, ponds etc. But, in the case of ocean andmarine areas as they are large and almost borderless in surroundings and several parameters like size of the area, water position, energy, quality are essentially to be investigated on real time. But in these, UWSN protocols sometime fail to receive the information from the sensor node which may be due to lack of power supply.In order to overcome this effect, reducing the data redundancy, better energy management and the data aggregation techniques are used with protocol wherein larger reading is collected and combined at the cluster head before transmitted to sink node[3][4]. In UWSN, various data aggregation techniques are used to monitor the areas on the basis of similarity, mobility, and distance with clusterbased approach and Mobile sink and Relay based as Non-cluster. The collected data are transformed to the sink or UW-Sink using the communication interface like acoustic, optical and electromagnetic waves.

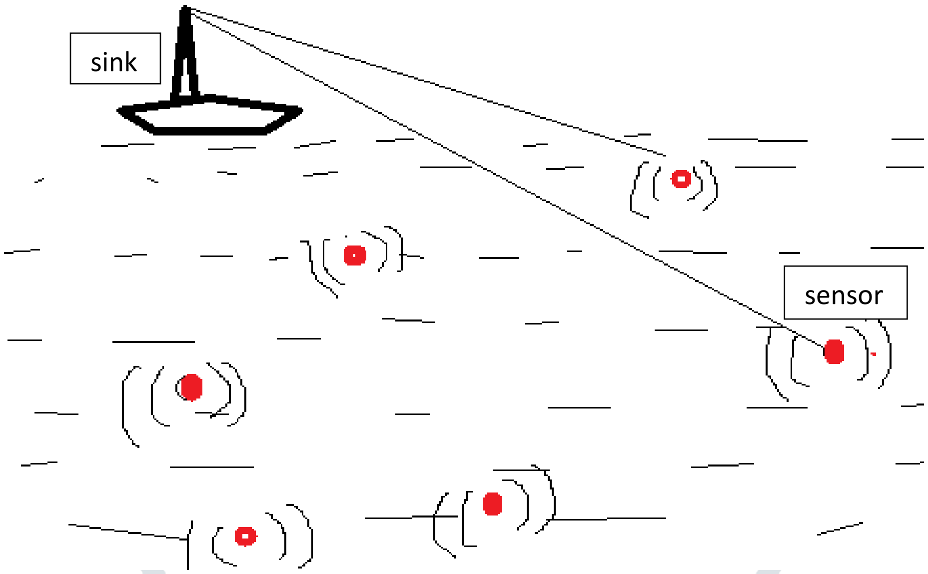

Fig. 1.1 A scenario of UWSN (Underwater Wireless Sensor Networks)

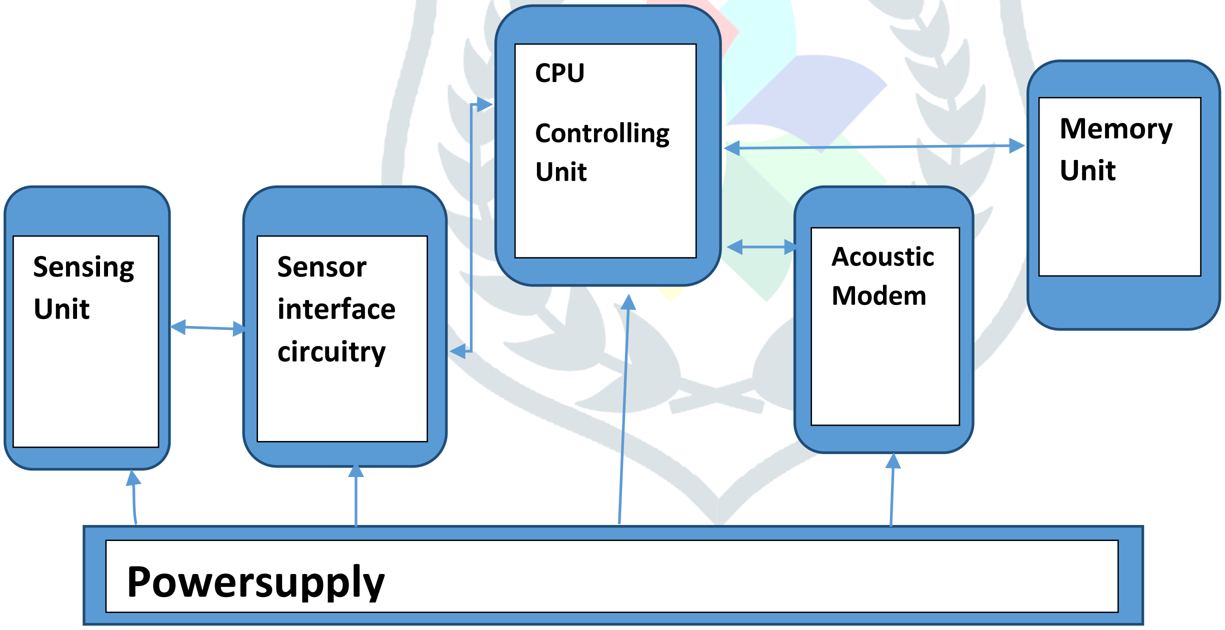

Fig 1.2. Architecture of a UWSN node

II CHALLENGES OF UNDERWATER WIRELESS SENSOR NETWORKS

2.1 Traditional research challenges of UWSNs

Themost popular and well known challenges of UWSN[11] are underwater noise, attenuation, limited bandwidth and propagation delay

2.1.1 Various underwater noise

Noise makes the quality of communications degrade.Hence routing protocols need to select the paths that have less effect of noise. The noise N can be summarized as

$$N=N_{shipping}+N_{wave}+N_{thermal}+N_{turbulence} \quad \ldots\ldots(1)$$

where $N_{shipping}$, the noise generated by shipping activities range from 20-200Hz, N_{wave} noise generated by waves(due to windblowing at the surface of water) ranges from 200-200kHz, $N_{thermal}$, thermal noise affects acoustic frequencies above 200kHz, $N_{turbulence}$, turbulence generated noise corrupts frequencies below 20Hz.

2.1.2Attenuation

The attenuation in underwater communications is a resultant of absorption loss and spreading loss. This ultimately affects the signal strength. The attenuation in dB of an acoustic wave of frequency f in kHz at a distance d from the source is denoted by A(d,f) and is expressed as

$$A(d,f)= A_0 d^k \alpha(f)^d \ldots\ldots\ldots(2)$$

where A_0 is the normalization constant, $\alpha$is the absorption coefficient and k is the spreading factor. In practice, k=1.5

2.1.3 Limited Bandwidth

There exists a limited range of available frequencies. The transmission range is inversely proportional to its bandwidth in underwater applications as shown in table2.1

Transmission Range(Km)	Bandwidth (KHz)
100	Below1
10-100	2-5
1-10	approx. 10
0.1-1	20-50
below 0.1	above 100

Table 2.1 Relationship of transmission range and bandwidth

2.1.4 Propagation delay of Acoustic waves[10]

The lower speeds of acoustic waves result in an inherent higher propagation delays in under water communications.These challengethe design of routing protocols for time-critical underwater applications like disaster applications and military operations.

2.2 Further challenges in UWSNs- Limited Energy and Network Lifetime

Limited battery power results in a short network lifetime for UWSNs. Routing protocols need to consider the energy balancing of the nodes to prolong the network lifetime. If nodes in a specific path are too frequently used then their energy gets depleted resulting in formation of energy holes. This hinders the network performance and affects the delivery of data packets towards the sink.

Thus, there exists the need for an increased throughput, reduced energy, and the enhanced network lifetime. Protocols and algorithms are needed to attend toconnection failures, unexpected mobility of nodes andbattery depletion.Design of the routing protocols with a better tradeoff among the node’s power and the node’s communicationoverhead are required.The aggregation methodology ought to be liberated fromcongestion.

III DEPTH-BASED ROUTING(DBR)

Depth-Based Routing (DBR) is the pioneering protocol within the transformation fromlocalization-primarily based [12] to localization-free routing in UWSNs [5]. This protocol uses the mobility of thesensor nodes to add scalability to the underwater networks. The water depth of the sensornodes is used as a forwarders' choice parameter. With this parameter, the movements of the nodeswith ocean currents do not require knowing the trade in position of the sensor nodes. The DBRdeploys five static sinks at the floor of the water and two source nodes at the lowest of the community.Source nodes experience the desired characteristic and forward the facts packets in the direction of the sink in a floodingmanner. Every node inserts its depth and ID data in the records packets to send. Upon receiving astatistics packet, each node holds it for a positive time, referred to as the conserving time. A forwarder node forwardsa received packet if it comes from a better depth node and otherwise discards it. The DBR has abetter packet delivery ratio and end-to-enddelay due to the selection of nodes with the lowest depthas relays. However, it suffers from redundant packets and excessive load at the nodes close to the sinks(low depth). Such nodes die quickly and create energy holes in the network. These holes affect the systemperformance in the later stage of network operation.

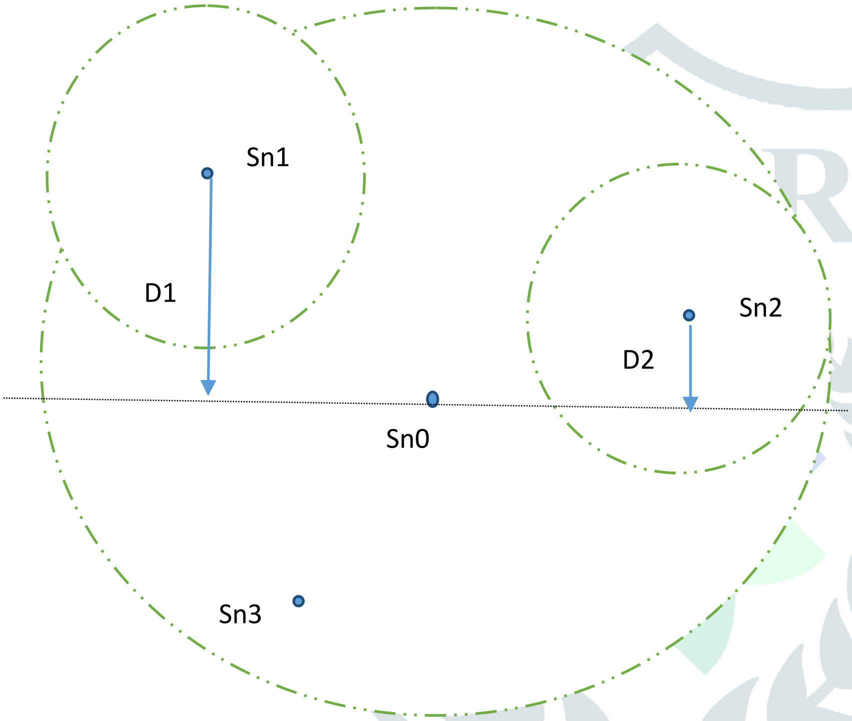

Fig. 3.1 choosing forwarding nodes in DBR

In DBR, each sensor node makes its own selection on packet forwarding based on its intensity and the intensity of the preceding sender. As seen in Fig. 3.1, consider for example, a sender nodeSn0, and its neighbor nodes, Sn1, Sn2, and Sn3, who receive its sent packets. However, only Sn1 and Sn2 are chosenbecause they are the nodes heading towards the sink node at the water surface. Further, node Sn1 is preferred to forward the packets compared to node Sn2. The forwarding of node Sn2 is avoided if it gets the packet from Sn1 earlier than its personal scheduled sending time for the packet. DBR can manage network dynamics efficiently without requiring full-dimensional location information of sensor nodes. But, if there are numerous neighbor nodes within the network, it is far very possibly that more than one node forwards the equal packets and a sensor node may additionally receive the identical packet more than one time, which ends up in a high extent of packet collisions and high transmission delay and power consumption. Therefore, in [7] a Delay-Sensitive Depth-Based Routing (DSDBR) protocol is proposed, which employs holding time to reduce end-to-end delay. Holding time is the residence time that the received packets can be stored on receiver nodes. The packets could be discarded after the holding time, which closely limits the packets transmission delay.

IV DEPTH-BASED ROUTING VARIANTs

4.1 Energy-Efficient Depth-Based Routing (EEDBR)[8]

An Energy-Efficient Depth-Based Routing (EEDBR)protocolkeeps thesystem energy balanced[9] and decreases the quantity of transmissions of sensor nodes so that one could improve the networklife time. In EEDBR, when a selection between the two forwarding nodes is to be made, the following parameters are considered: Among two nodes whichever has lower depth is selected. But, when two nodes have same depth, a node with higher residual energy is selected. Further, if two nodes possess same residual energyand are at similar depths, still their holding time varies. Finally, one node will transmit the packet and the other will suppress its transmission upon overhearing the transmission of the same packet. Thus, the suppression of the packet transmissions contribute to reducing the energy consumption, improving energy efficiency. But, increased suppression of packet transmissions affects the delivery ratio. To handle this situation, the suppression scheme is carefully planned such that, when the delivery ratio is less than a given delivery ratio threshold, the number of nodes which suppress their packet transmissions is reduced to meet the desired delivery ratio.

EEDBR comprises of two stages: knowledge acquisition phase and data forwarding phase. During the knowledge acquisition phase sensor nodes share their depth and residual energy information among their neighbors. In the Data Forwarding Phase, the datapackets are forwarded from a source node towards a destination/sink node on the basis of the depth and the residualenergy information of the sensor nodes.

(a)Knowledge acquisition phase

In the Knowledge Acquisition phase, the sensor nodes share their depth and residualenergy information among their neighbors. The motivation behind this sharing is to enable the sensor nodes to choose the most appropriate neighbors as forwarders during the Data Forwarding phase. Whenever a sensor node has a data packet to send to the sink node, the depth and the residual energy data are utilized in the determination of forwarding nodes. In this knowledge acquisition phase, learning implies the depth and remaining energy of a sensor node. The Knowledge Acquisition phase works as follows. Each sensor node communicates a Hello packet to its one hop neighbors. The Hello packet contains the depth and the remaining energy of the broadcasting node. After getting the Hello packet, the neighboring nodes just store the data about the sensor nodes having smaller depths,because the data packets are to be obviously transmitted towards the sink nodes living on the water surface. Hence, it is not required to store the depth and residual energy data of all the neighboring nodesthereby reducing the burden of storing huge data. It is reported that, in UWSNs, the sensor nodes live at similardepths. This is on the grounds that the sensor nodes move with water flows in horizontal direction,and the movements in vertical heading are nearly negligible[4]. Consequently, the updating of the depth data is not critical. But,the residual energy of the sensor nodes changes over time due to the different operations, that is, transmitting, receiving, processing, and idle listening. Therefore, the residual energy information of the sensor nodes needs to be updated. For this reason, a dispersed methodology is utilized. Every sensor node checks its remaining energy on an interval basis.If it observes that there is a distinction between the current and past residual energy of a sensor node and is bigger than a threshold (i.e., predefined), that sensor node communicates the Hello packet including the update residual energy to its one hop neighbors. Thus, the remaining energy data of the sensor nodes is refreshed among the neighboring hubs. Moreover, the Knowledge Acquisition phase is executed on an interval basis. This is done to refresh the sensor nodes about their latest neighboring nodes, their refreshed remaining energy and depths. In any case, the interval of Knowledge Acquisition phase is set in order to dodge the overhead caused due to the Hello packet broadcasts. Thus, there is a trade-off between the overhead and having the refreshed data about the neighboring nodes.

(b)Data Forwarding Phase

In Information forwarding phase, the information parcels are sent from a source hub towards a goal/sink hub based on the profundity and the lingering vitality data of the sensor hubs. The data about the profundity of the sensor hubs permits the determination of those sending hubs which are nearer to the sink than the sender of the information parcel. Also, the leftover vitality data about the sensor hubs is utilized to choose the hub having high lingering vitality among its neighbors. The determination of the hub having high vitality endeavors to balance the vitality utilization among the sensor hubs. InEEDBR, since every sensor hub has the data about its neighbors' profundity and the lingering vitality, a sending hub can choose the most appropriate next bounce sending hubs. Accordingly, the sending hub chooses a lot of sending hubs among its neighbors having littler profundity than itself. The set of sending hubs is incorporated as a rundown of IDs in the information parcel. After getting the information parcel, the sending hubs hold the packets for a specific time dependent on their remaining energy. The sensor having more residual energy has a short holding time. The holding time (T) is computed using the equation (3).

$$T = (1-(\text{current energy}/\text{initial energy})) * \text{max holding time} + p \qquad \ldots..(3)$$

where max holding time is a framework parameter (i.e., the greatest holding time a node can hold a packet), and p is the needed priority value**.** The neededpriority value is utilized to keep various sending nodes from having a similar holding time since the sensor nodes may have a similar residual energy level. In this way, ifthe holding time is onlybased on the residual energy, the nodes having same remaining energy will likewise have a similar holding time. In such a case, the forwarding nodes will forward the packet at the same time. Thus, redundant packets will be transmitted.In order to avoid such transmissions, the priority value is added to the holding time all together to have the effect among the holding times of the sending nodes having a similar residual energy. The priority value is computed as follows. The sendingnode sorts the forwarding list based on the residualenergy of the forwarding nodes. Upon receiving the datapacket, the forwarding nodes add the priority value to theholding time based on their position in the list. The priorityvalueisinitializedwithastartingvalueandthepriorityvalueis doubled with the increase in the position index of thenodes in the list. Hence, due to the different positions in thelist, the nodes have different priority values. Consequently,the nodes having the same residual energy will have differentholding times even for the same packet.Interestingly, in DBR, the distinction between the holding times of the sensor nodes having comparative depths is not sufficiently long for over hearing.Hence, redundant packet transmissions are unavoidable in DBR.

In EEDBR, the topmost node in the list has the highest priority due its highest residual energy among its neighbors. Hence, a holding time of zero is utilized for the topmost node in the listso as to diminish the end-to-end delay. The topmostnode will forward the data packet when it gets the data packet. During the sending of the data packet based on the depth and residual energy, diverse situations are conceivable.When a situation arrives where two nodes have same depths and similar residual energy levels, still they both have diverse holding times, one hub will transmit the packet, and the other will suppress its transmission upon receiving the transmission of a samepacket. In UWSNs, such a suppression of packet transmissions improves energy efficiency.However,too much suppression of packet transmissions influences the delivery ratio. In a few applications, for example, military operations, the delivery ratio is considered more important than the energy efficiency.Hence,in support to such applications, an application-based suppression scheme is utilized. In thescheme, when the delivery ratio is not as desired, the number of nodes which suppress their packet transmissions is diminished so as to meet the ideal delivery ratio. During the forwarding of the data packets, the source incorporates the number of packetsgenerated by that source. After getting the data packets, the sink node processes the delivery ratio by dividing the number of data packets received at the sink to the number of data packets generated by the source node. Based on this delivery ratio it is decided whether to suppress the packet transmission or not thus having a tradeoff between the delivery ratio and energy efficiency.

4.2 Delay-Sensitive Depth-Based Routing(DSDBR)[7]

Delay-Sensitive DBR DSDBR is an enhanced version of DBR, which not only does the routing on the basis of depth information but also employs Holding Time (H_T) and Depth threshold (D_T). Each sensor node transmits the sensed data inside its transmission range.The neighbor node, at a depth lower than the source node and is located outside its D_T limit, computes H_T for received data packet.

Depth threshold is given as:

$$D_T < D_p - Dc \ldots\ldots(4)$$

where dc and dp denote the depths of the current and previous nodes respectively all through transfer of a packet.

Data Forwarding Phase

DSDBR works at the principle of greedy set of rules and nodes with a lower depths forward records in the direction of Base Station(BS). Each eligible neighbor computes Forwarding cost Fr for the received packet as follows:

$$Fr = (TL_r S_r / \eta) \ldots\ldots.(5)$$

where S_r is the speed of the received data packet in m/s, TL_r is the transmission loss of received packets in dB and η is a scaling factor for Fr.

Fr relies upon Transmission Loss (TL) and velocity of received data packets which is used to discover intermediate forwarder in transmission range. Fr is used to compute WF for obtained packet, that is expressed as:

$$WF = c - Fr \qquad \ldots\ldots.(6)$$

wherec is used as a constant and depends upon the network size. The value of WF determine the difference between the Fr values of neighbors of the source node, that is, in addition applied to calculate HoldingTime(H_T). Nodes having high Fr could have low WF as well as Holding Time (H_T) , that is computed as:

$$H_T = \frac{WF \quad HTmax}{Vac \quad TLmin} \ldots\ldots.(7)$$

Using the equation (7), each node calculates H_T for acquired packet at some stage in which, it maintains information packet in buffer. TLmin is the minimal transmission loss among any two nodes in dB and V_{ac} is the velocity of acoustic signal in m/s. $H_T$max is the max value of H_T for any obtained packet. An optimum value of H_T is used to minimize more than one transmission of equal packets, as nodes overhearing the received packets from low-depth nodes will now not transmit the received data packets. Therefore, DSDBR objective is to decrease end-to-enddelay with the aid of improving H_T computation standards and WF formula. However, there may be a trade-off between end-to-end delay and throughput in the stability period.

4.3 Delay-Sensitive Energy-Efficient Depth-Based Routing (DSEEDBR)[7]

Delay-Sensitive Energy-Efficient DBR, DSEEDBR gives stronger community lifetime along with delay sensitivity to EEDBR through imposing adaptive variations in depth for sensor nodes and Delay-Sensitive Holding time (DS HT). DS HT is the heart of depth-based totally routing model and gets rid of the inadequacy of multiple relative transmissions in EEDBR. Every receiving node before forwarding the data packet, computes the transmission loss and noise loss of the channel and depth difference in orderto predict the time-lag of the packet to be forwarded.

a) Variants of D_T

DSEEDBR exploits the inefficient technique of a constant**(D_T)**depth Thresholdin the entire network which causes more delay in the low-depth region. Transmissions by sensor nodes in the low-depth region causes excessive propagation delays. These transmissions may reduce the load on medium-depth region nodes on the cost of high noise loss in the upper region.These losses are computed along with considerations about the residual energy of medium-depth nodes and apply variable D_T for nodes according to their depth data. The sensor nodes deployed in low-depth and medium-depth areas have smaller D_T values than the high-depth nodes therefore, they may have increased quantity of neighbors avoiding distant transmissions.

b) Delay-Sensitive Holding time (DS H_T)estimation

The scheme proposes quicker data forwarding mechanism than EEDBR by estimating DS H_T for forwarding statistics packets. After receiving those packets, eligible forwarders bear in mind attenuation loss in computing DS H_T. Since, it is energy efficient because it utilizes residual energy of the forwarder node, therefore DS HT is computed as:

$$DS\ H_T = (A_L D_d E_r)/(L_N\ Vac\ E_{ini}) \quad ....(8)$$

where$A_L$denotes attenuation loss of received packets in dB, D_d is the Depth difference among sender and receiver node in meters and E_r is the residual energy of a receiver node in joules. L_N is the blended noise loss due to shipping, wind, turbulence and thermal activities in dB. Vac denotes speed of acoustic signals and E_{ini} shows the initialenergy of nodes. Node having low A_L and D_d may have lesser DS H_T than the other neighbors and will be decided on as suitable forwarder**.**

VPERFORMANCE EVALUATION OF DEPTH-BASED ROUTING VARIANTS FOR UWSNs

A]EVALUATION OF DBR AND EEDBR

(a) DBR makes use of only the depth of sensor nodes without considering the residual power ofthe sensor nodes. Similarly, in DBR, there may beno approach/method for energy balancing amongsensor nodes. When compared to DBR, in EEDBR scheme,the energy balancing of sensor nodes is employed inorder to enhance the network life-time.

(b) In DBR, the wide variety of forwarding nodes will increaseas the network density increases. But, in EEDBR scheme, the number of forwarding nodes isconstrained not juston theirdepth basisbut also ontheir residual energy basis.

(c) DBR is a receiver-based method, where the receiving nodes determine whether to forward the received data packet or not. There may be a high possibility of redundant transmissions in a receiver-basedmethod due to the lack of neighboring nodes informationsuch as depth and residual energy. Incomparison, EEDBR is a sender-based approachwherein the sender makes a decisionabout the forwarding nodes, primarily basedon the neighboring nodes' depths and residual energystatistics. For this reason, the sender can select a restrictednumber of suitable forwarding nodes.

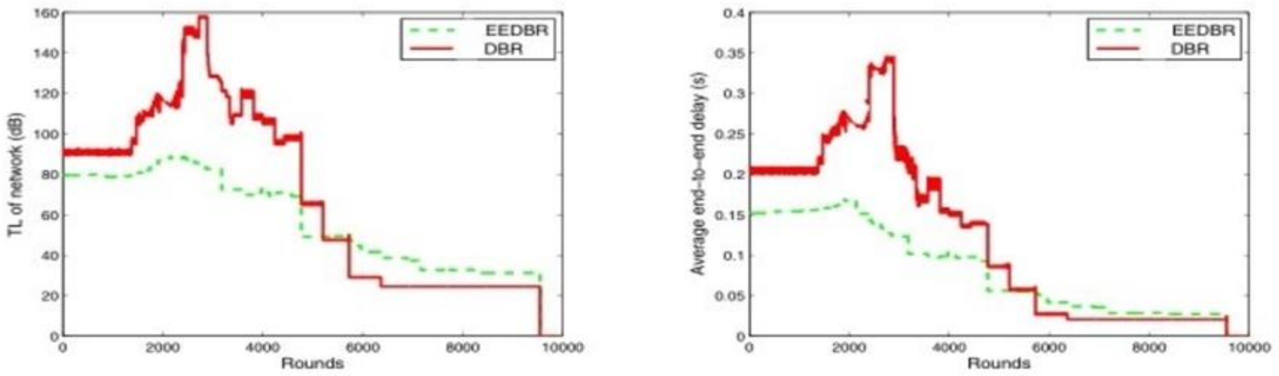

Fig. 5.1. (a) Transmission Loss in DBR and EEDBR (b) end-to-end delay in DBR and EEDBR

Fig.5.1(a)presents the evaluation of TL for DBR and EEDBR.It shows that transmission loss is better in EEDBR than in DBR scheme, which is as a result of a massive quantity of transmissions and multiple retransmissions for same packets. In DSEEDBR, because of excessive network density in preliminary rounds, there may be lesser transmission loss which will increase dramatically with a decrease inside the number of available forwarders in low-depth regions. DSEEDBR continues low TL for the duration of the networklifetime with the aid of reducing load on low-depth nodes. Fig.5.1(b)depicts the end-to-end delay in DBR and EEDBR. It indicates gradual decrease in delay of EEDBR in conjunction with modifications in TL of the network. It illustrates slower network interest in DBR which is not suitable for time-crucial applications. After 2000 rounds, there is a sharp growth in delay of DBR due to short energy intake of nodes deployed in medium-depth area. EEDBR decreases end-to-end delay of the network with the aid of residual energy parameter for forwarders choice.

B] EVALUATION OF DBR AND DSDBR

Fig.5.2(a) depicts that in DBR, number of packets received by sink are higher than DSDBR. In the initial rounds, throughput of DSDBR is lower than DBR due to low stability period. It reduces the number of available forwarding nodes for remaining alive nodes. Fig.5.2(b) shows the decrement in average end-to-end delay of DSDBR compared to DBR. After 5000 rounds, there is a larger decrease in delay of DSDBR on the cost of small decrement in network density. However, in DBR, there is a raise in end-to-end delay which is basically because of excessive TLs for ultimate distant nodes. During the instability period of DSDBR, throughput stays higher than that of DBR along with minimum energy consumption and lesser end-to-end delay as observed in figs.5.2(a) and 5.2(b). The main reason for decreased delay in DSDBR in later rounds is low network density and availability of appropriate data forwarders.

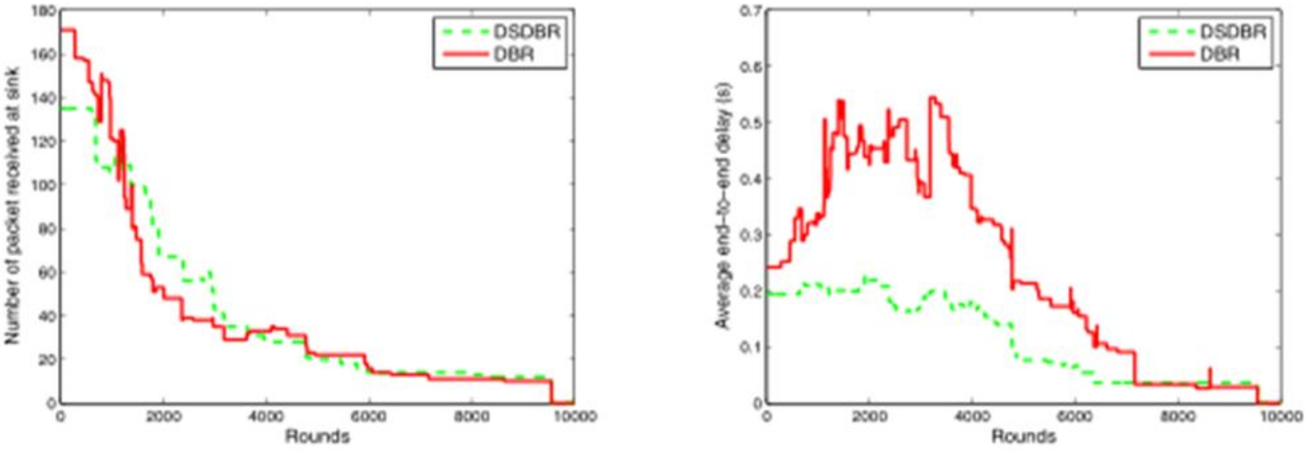

Fig. 5.2 (a) Network throughput in DBR and DSDBR (b) end-to-end delay in DBR and DSDBR

DBR and DSDBR are evaluated to analyze the functioning of DSDBR in phrases of various performance parameters. DSDBR faces tradeoff between end-to-end delay and throughput of the network. In the earlier rounds of DBR, there is a raise in number of transmissions which will increase the UWSN throughput together with end-to-end delay. Fig.5.2(a) depicts that in DBR, range of packets obtained by sink are higher than DSDBR. in the preliminary rounds, throughput of DSDBR decreases than DBR due to low stability duration. It reduces the number of available forwarding nodes for the lasting alive nodes.

C] EVALUATION OF EEDBR AND DSEEDBR

In fig.5.3 (a), evaluation of TL for EEDBR and DSEEDBR illustrates that transmission loss is better in EEDBR than the proposed scheme, which is as a result of a massive quantity of transmissions and multiple retransmissions for same packets. In EEDBR, because of excessive network density in preliminary rounds, there may be lesser transmission loss which will increase dramatically with a decrease inside the number of available forwarders in low-depth regions. DSEEDBR continues low TL for the duration of the network lifetime with the aid of reducing load on low-depth nodes. Fig.5.3(b) depicts end-to-end delay in EEDBR and DSEEDBR. It indicates gradual decrease in delay of DSEEDBR in conjunction with modifications in TL of the network. It illustrates slower network interest in EEDBR which is not suitable for time-crucial applications. After 2000 rounds, there is a sharp growth in delay of EEDBR due to short energy intake of nodes deployed in medium-depth area. DSEEDBR decreases end-to-end delay of the network with the aid of incrementing D_T in excessive-intensity location for forwarder choice thinking about low attenuation and noise losses in this location. Delay sensitivity based routing compromises on network throughput to acquire low propagation delay.

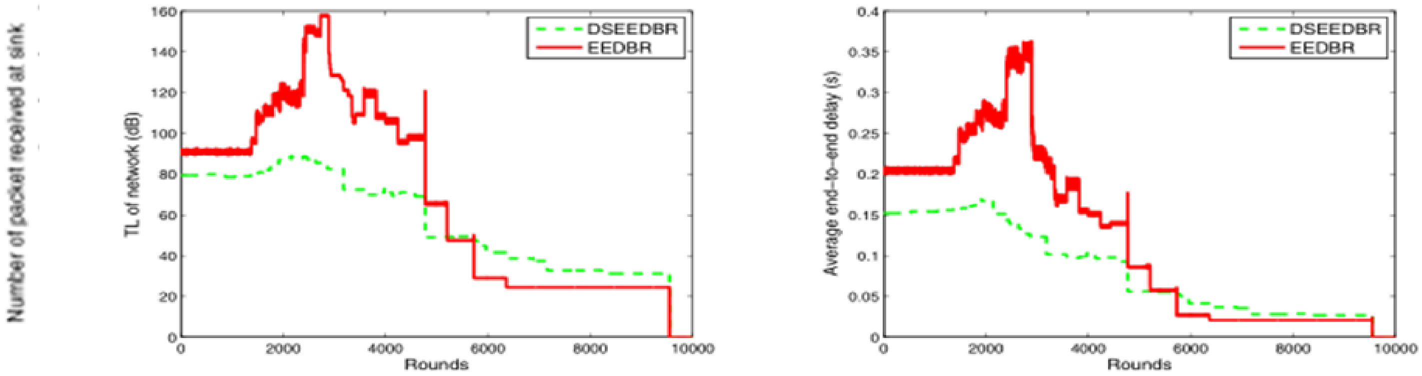

Fig. 5.3 (a) Transmission Loss in EEDBR and DSEEDBR (b) end-to-end delay in EEDBR and DSEEDBR

VIII CONCLUSION

This paper presents comparison and evaluation of basic Depth Based Routing protocol(DBR) and its variants such as (DSDBR) Delay Sensitive DBR(EEDBR),Energy Efficient DBR and Delay Sensitive Energy Efficient DBR (DSEEDBR) used in UWSNs. These protocols are seen as improvement to localization-free routing schemes.Furthermore, in DBR, with the increase in network density, the number of redundant transmissions also increases because the probability of small difference among nodes' depths also increases with the network density and the nodes having similar depths also have similar holding times. It suffers from redundant packets and excessive load at the nodes close to the sinks (low depth). Such nodes die quickly and create energy holes in the network. It is observed that distant transmissions in the low-depth region are the significant causes of propagation delays.DSDBR along with node's depth alsotakes into account the Holding time $H_T$with a main focus to reduce the redundant packets.EEDBR believes that an issue of residual energy is more significant than an issue of node's depth. Hence, nodes with less depth valueand high residual energy value are chosen as forwarders.DSEEDBR computes DS H_T Delay sensitive Holding Time(H_T). Nodes with lesser value of DS H_T are selected as forwarders. This scheme decreases end-to-end delay of network by increasing the depth threshold D_T. These studies indicate the need for the development of new protocols which can be extra smart, strong and novel withthe preferred parametersconsidering all the underlying issues for efficient routing in Underwater wireless sensor networks.

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