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Environment Adaptive Energy Efficient Depth Based Routing Protocol for Underwater Wireless Sensor Networks

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ABSTRACT
Background: About more than 70% of the Earth's surface is surrounded by aquatic environment which corresponds to mostly unexplored area. Underwater wireless sensor networks have recently been proposed as an innovativeway to observe and explore these harsh environments. However, the efficient data delivery is still a challenging issue in these networks because of the impairments of the acoustic transmission.Thus, providing an efficient routing algorithm becomes a significant mission.**Objective:**This study aims to propose a novel Environment Adaptive Energy Efficient Depth Based Routing protocol to guarantee for higher network life time, less total energy consumption and less end to end delay. The protocol does not use control packets to discover the routing path. Instead, information of control packet is incorporated in the data packet thus reducing the unnecessary energy consumption and minimizes end to end delay. **Results:**Extensive analytical simulation is executed to attest the competence of the proposed protocol. The results analyzed illustrate that it outperforms the existing Depth Based Routing protocol in terms of total energy consumption and average end to end delay. **Conclusion:**A novel routing protocol named Environment Adaptive Energy Efficient Routing Protocol for UWSNs that promises the best use of total energy consumptions is proposed.

INTRODUCTION

About two-third of the earth is covered by water. This huge unexplored area of water is continuously being explored with a view to discover hidden knowledge and unknown resources in the ocean. The research under water is being accomplished for the purpose of many kinds of application such as ocean sampling networks, environmental monitoring, undersea explorations, disaster prevention and mine reconnaissance (F. Akyildiz *et al.*, 2004, J. Heidemann *et al.*, 2005, J.A.Rice, 2002). Underwater Wireless Sensor Network (UWSN) has been emerged as an interesting research area in recent years that helps in investigating the vast area under water and provides vital information to the surface. UWSNs have to face some challenges such as varying sound velocity, node mobility, limited battery, limited bandwidth and multi path noise. In UWSNs, the node moves with the velocity of 3-6km/h (L. Guo, 1995) because of water current. So, it is not possible to progress routing protocols which works with the whole topology. Moreover, the battery of underwater sensor node cannot be recharged or changed because of harsh under water environment. The propagation speed of acoustic signals in ocean is varying. Sensor nodes of underwater sensor networks move with water current which results in dynamic topology.

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One of the primary topics for any network is routing and routing protocols are regarded as indictment of determining and preserving the routes. Most of the research works pertaining to underwater sensor networks have been on the issues related to physical layer. On the other hand, routing techniques are comparatively new arena of network layer of UWSNs. Although underwater acoustic has been continued to study for decades, underwater networking and routing protocols are still at the infant stage of research. Some routing protocols have been proposed to deal with the challenges posed by the unique characteristics of underwater acoustic communication channel. But most of these protocols espouse the greedy technique to forward packets to the neighboring node which consumes a lot of energy when network is dense. So, some of the existing routing protocols have been studied to shape the proposed routing protocol.

DBR (H. Yan *et al.*,2008) is the first depth based routing protocol which employs depth information only in order to find the next forwarder nodes. The first variant of DBR named DBMR(L. Guangzhong and L. Zhibin, 2010) is a multi-hop depth based routing protocol which employs depth information with residual energy and assigned node IDs in order to find best single path towards the sink. Moreover, EEDBR (A. Wahid and D. Kim, 2012)is the second variant of DBR which utilizes depth information with residual energy and calculates a priority value for each of the forwarder nodes. EEF (M. Ashrafuddin*et al.*,2013)is the third variant of DBR which calculates a fitness value for each forwarder node using a new formula using residual energy and depth information. Unlike these protocols, Hydro Cast (U. Lee *et al.*,2010)and VAPR (Y. Noh *et al.*,2013)utilize link quality for their void handling mode for finding a detour path and VAPR uses an enhanced beaconing in the first mode and employs a hop count and sequence number during forwarding process. Finally, AMCTD (M. Jafri *et al.*,2013)employs a courier node with residual energy, depth and weight value in order to choose the next forwarding nodes. Employing different parameters such as residual energy, link quality, hop count and node ID may have a direct effect on the performance of the network such as network lifetime, reliability, end-to-end delay and packet delivery ratio.

All of these discussed routing protocols for UWSNs are efficient and effective in their own ways. But, all of these protocols use the constant value for sound speed at 1500 m/s. But, in real time underwater scenarios, sound speed varies significantly at various depths and it ranges from 1450 m/s to 1540m/s. In this context, in this paper, a novel routing protocol that exploits the varying acoustic channel parameter of sound velocity has been devised by cogitating upon limited battery and limited bandwidth. The proposed routing protocol provides shorter end to end delay and evades control packets to guide data packet to the destination entirely which hoards up huge amount of total energy. In DBR, the forwarding node takes the decision of packet forwarding based on only depth which can make more forwarding nodes compatible to forward a packet because of node's same depth. In EAEEDBR, decision of packet forwarding is based on the node's depth, residual energy, and distance from the sending node to the forwarding node and distance from the forwarding node to the sink node and the variable sound velocity. Packet holding time is computed based on the above said parameters for the purpose of making each forwarding node's waiting time different after receiving packet thus resulting in higher energy efficiency.

MATERIALS AND METHODS

Environment Adaptive Energy Efficient Depth Based Routing Protocol for UWSNs:

In this section, Environment Adaptive Energy Efficient Depth Based Routing Protocol (EAEEDBR) for UWSNsis presented and discussed in detail. Network architecture, overview of EAEEDBR and finally routing algorithm of EAEEDBR are presented.

Network Architecture:

Multiple-Sink underwater sensor network architecture (H. Yan *et al.*, 2008) for EAEEDBR is demonstrated in Fig. 1.

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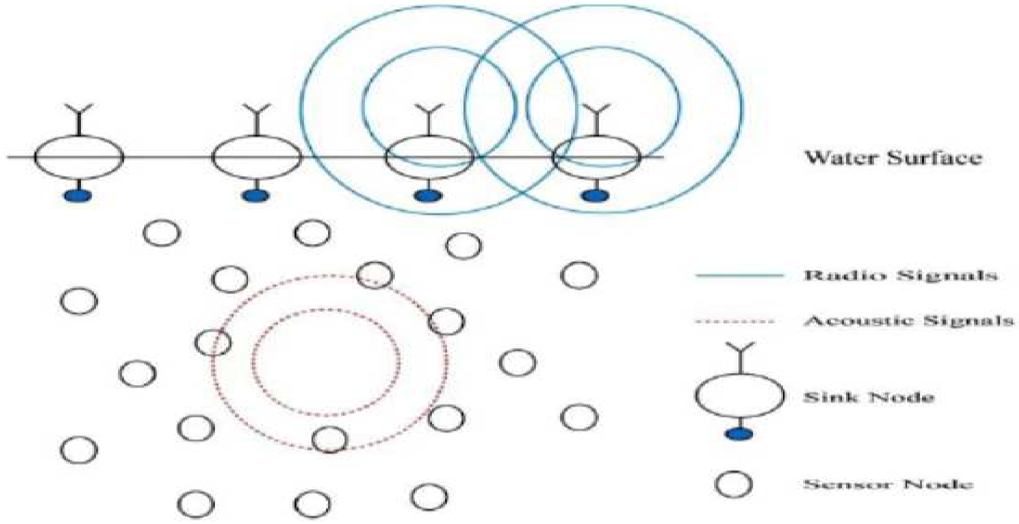

Fig. 1: Multiple-sink network architecture for UWSN

In this multiple-sink network, the water surface nodes that are called sink nodes are equipped with the modem that is capable of capturing both radio-frequency and acoustic signal. The nodes that send and receive only acoustic signal are deployed in the underwater environment. Underwater sensor nodes with acoustic modems are placed in the interested area and each such node is assumed likely to be a data source. Underwater acoustic nodes can accumulate data and also assist to convey data to the sinks. When a sink node receives a packet from an underwater acoustic node, the sink node can converse with each other efficiently via radio channels. The protocol attempts to send a packet to any sink nodes on the surface because if a surface node receives a packet it can send the packet other sinks or remote data centers quickly due to the speed of radio-frequency which is five orders of magnitudes higher than sound propagation. Here, the protocol does not pay attention to the communication between surface nodes. Instead it tries to transmit a packet to any surface sinks and assumes that the packet reaches to its destination. The protocol has been built by considering the fact that every node knows its depth which is the vertical distance from the node's position to the surface and its position.

Overview of Environment Adaptive Energy Efficient Routing Protocol for UWSNs:

In the proposed routing protocol, it is assumed assume that the location of the sink node is known. The protocol works as the following way: First, the source node calculates the fitness of its own and incorporates the fitness value and its position in the data packet and broadcasts it. The one hop neighboring nodes which get the packet calculate their own fitness that actually define whether they forward the packet or simply discard. After receiving the packet, the forwarding node compares its fitness with the sending node's fitness incorporated in the packet. If the fitness of the forwarding node is greater than that of the sending node, then it forwards the packet otherwise it discards the packet. In this process, more nodes may take part in forwarding packet; In order to prevent more nodes to forward the same packet, the forwarding nodes wait for a time period which is assumed based on the residual energy, depth, and distance from the sending node to the forwarding node. The holding time of the forwarding nodes vary from each other. The node which is the fittest waits less time than that of other forwarding nodes. Consequently, other forwarding nodes overhear the same packet and avoid forwarding the packet.

Protocol Design:

Notations used in the design of the protocol are listed below:

SN – Sending Node;
FN – Forwarding Node;
DN – Destination Node;
RE_s– Residual Energy in Sending Node;
RE_f – Residual Energy in Forwarding Node;
SNF –Fitness Factor inSending Node;
RDF –Routing Decision Fitness in Forwarding Node
HLDTIME– Holding Time

1) Packet Format: The Packet used by the proposed protocol is demonstrated in Table 1.

Table I: Data Packet Format

SID	PSN	SNF	SNL	STP	DATA

The packet header consists of the five fields: Sender ID (SID), Packet Sequence Number (PSN), Sender Node Fitness (SNF), Sending Node's Location Depth (SNL), Sending Time of Packet (STP) and Data. "Sender ID" is the identifier of the source node. "Packet Sequence Number" represents a unique sequence number that is assigned by the source node to the packet. Packet Sequence Number together with Sender ID is required to differentiate packets in later data forwarding.

Routing Decision Fitness Factor Computation:

The fitness factor is calculated with the help of node residual energy, depth and distance from the node to the sink, the distance from the forwarding node to the sending node and the sound velocity at the location of the sending node and destination node. The more residual energy is, the more capable the node is to forward the packet, the less the depth, the more suitable the node is to be chosen as forwarding node that means more positive depth difference between the forwarding node and the sending node, the more capable the forwarding node is to broadcast the packet. The more the distance between the sending node and the forwarding node the less time the packet reaches sink node. Hence by considering such kind of properties of residual energy, depth difference and distance between the sending node and the forwarding node with packet forwarding, a relation can be developed between these parameters to take the decision of packet forwarding. Routing Decision Fitness is computed as follows:

$$RDF = \frac{RE_f \times DD \times DSF \times SV}{DFD} \quad (1)$$

where,
RDF is the routing decision fitness in forwarding Node
DD is the difference between depth of sending and forwarding node
DSF is the inter node distance between sending and forwarding node
DFD is the inter node distance between forwarding node and destination node
SV is the sound velocity at the location of forwarding node
RE_f is the residual energy of the forwarding node.

Though the location information of node is not known accurately, the inter node distance between the sending node and forwarding node and the inter node distance between the forwarding node and the sink can very well be computed using the time difference of the sending time and receiving time of the packet and the speed of the sound at the location of the node receiving the packet. Distance between the sending node and the forwarding node and Distance between the sink node and the forwarding node are computed as follows:

$$DSF = SS_f\,(RPT - SPT) \quad (2)$$

where,
SPT and RPT are packet sending time incorporated in the data packet sent and packet receiving time at the forwarding node respectively.
SS_fisthe sound speed at the forwarding node

$$DFD = SS_k\,(RBT - SBT) \quad (3)$$

Where,
SBT and RBT are beacon sending time from the sink node and beacon receiving time at the forwarding node.
SS_kisthe sound speed at the sink node
The less the distance between the destination node and the forwarding node and the more the sound velocity at the location of the forwarding node, the more appropriate the node is to forward the packet.

Calculation of Holding Time:

The waiting time for the forwarding node is calculated before broadcasting the packet. The node with higher depth, higher sound velocity, more distance from the sending node to the forwarding node, less distance from the forwarding node to the sink node and higher residual energy wait for less time. The higher fitness, the less time the forwarding node waits. The ultimate waiting time is calculated as follows:

$$HLDTIME = \left(\frac{1}{RDF}\right) + \left(\frac{D}{V}\right) \quad (4)$$

where,

HLDTIME is the Holding Time (s)
RDF is Routing Decision Fitness in Forwarding Node
V is the sound velocity (m/s) at the location of forwarding node
D is the maximum distance that a forwarding node can have within the communication range of sending node (m).

Each node after receiving the packet from the previous node waits for a period of HLDTIME. The most suitable forwarder node has less time to wait. The other nodes overhearing the packet before the expiry of the HLDTIME waiting time will discard the packet.

Routing Algorithm:

The proposed routing algorithm is presented below in detail.
Input packet received.
Extract the values from the required fields of the packet
If RE_f> Threshold Energy, then Calculate RDF and HLDTIME.
If RDF > SNF, then
Wait For HLDTIME Period
Broadcast packet
Else
Discard the packet;
End if
Else
Discard the packet
End if

RESULTS AND DISCUSSIONS

In this section, the effectiveness of the performance of the EAEEDBR is validated through extensive simulations and its performance is compared with the performance of DBR (Yan *et.al*., 2008).

Simulation Setting:

All simulations are performed using MATLAB. In our simulations, sensor nodes are deployed in a 1500 m ×1500 m ×1500 m 3 D area. The position of each node is generated randomly. Multiple sinks are randomly deployed at the water surface. Sink nodes are considered as stationary while the sensor nodes are considered to be mobile at the speed of water current. In order to measure the performance of EAEEDBR, different speed of water current are considered and the minimum and maximum speed of water current are taken 1m/s and 5m/s respectively. In underwater environment, the sensor nodes move in random direction, for easy simulation the direction of each sensor node in 3D space is defined randomly. Each node generates two packets per second and the size of data packet is 76 byte and the size of control packet is 32 byte and bit rate is 10kbs.The transmission range of the sensor node is fixed 100m in all directions. The sound velocity at different depths is calculated using the empirical formula. The total power consumption in sending, receiving and idling mode is assumed 3w. The threshold energy of the sensor nodes is presumed 80 Joule. The variable sound speed is computed using empirical formulae at each node from the measured parameters of temperature, salinity and pressure.

Performance Metrics:

The performance metrics used appraise the performance of EAEEDBR are Network Life Time, Total Energy Consumption, Average End to End delay and Packet Delivery Ratio.

Network Life Time: Network life time expresses the time that the energy of the first node in the network turns into to be fully exhausted. *Total Energy Consumption:*Total energy consumption is computed through the total energy consumed in packet delivery including transmitting, receiving, and idling energy consumption of all nodes relaying the packet from the source node to sink node in the network. *Average End-to-End Delay:* Average end-to-end corresponds to the average time needed by a packet to go from the source node to any of the sinks. *Packet Delivery Ratio:*Packet delivery ratio is evaluated as the ratio of the number of distinct packet captured successfully by the destination node to the total number of packets spawned at the source node.

Results Analysis:

In this section, results of the proposed EAEEDBR protocol are analyzed against different values of performance metrics and compared with the results of the existing DBR protocol.

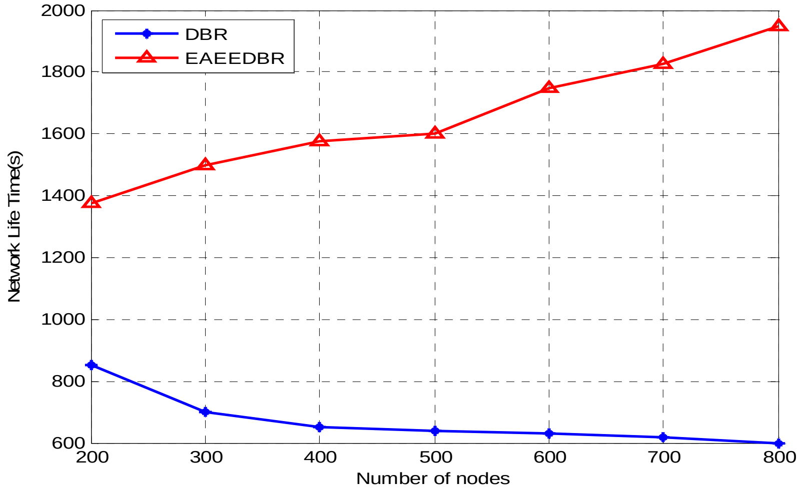

Fig. 2: Comparison of network life time

The network life time of EAEEDBR and DBR in random topology is illustrated in Fig. 2. It is observed that EAEEDBR offers improved performance over DBR in the perspective of network life time. EAEEDBR exceeds the network life-time of DBR because DBR always chooses the sensor nodes with smaller depth to forward data as a result a senor node with the smallest depth may be selected again and again to forward data. Consequently, the energy of such nodes is exhausted fast and these nodes' life-time expires soon. On the other hand, EAEEDBR does not forward data to the sensor node with residual energy less than the threshold energy and always selects the sensor node with higher residual energy. There is a little chance for a senor node to go down its energy below threshold and dies. So, the network life-time increases as the number of sensor node increases. Besides, DBR cannot avoid redundant packet transmissions. But in EAEEDBR, only one sensor node has data to send thus saving energy to improve the life time of battery.

The total energy consumption of EAEEDBR and DBR in random topology is illustrated in Fig. 3. In DBR, the amount of energy is consumed much when the velocity of current and the number of sensor nodes increase since multiple sensor nodes become forwarding node as they do not overhear one another within the fixed range. On the contrary, in EAEEDBR, data packets are sent to a senor node after being convinced that the target sensor node and the forwarding sensor node stay within the fixed range of the forwarding node for a predefined time. At every time, only one sensor node becomes the forwarding node in EAEEDBR which causes a less amount of energy consumed than that of DBR.It is inferred that for dense network, it does not consume significant amount of additional energy consumption because it does not matter how many neighboring sensor nodes the forwarding sensor node have. It always chooses only one candidate sensor nodes to forward packet. Although at this time, control packets generate a little amount of energy consumption. In EAEEDBR, node mobility slightly impacts on the total energy consumption.

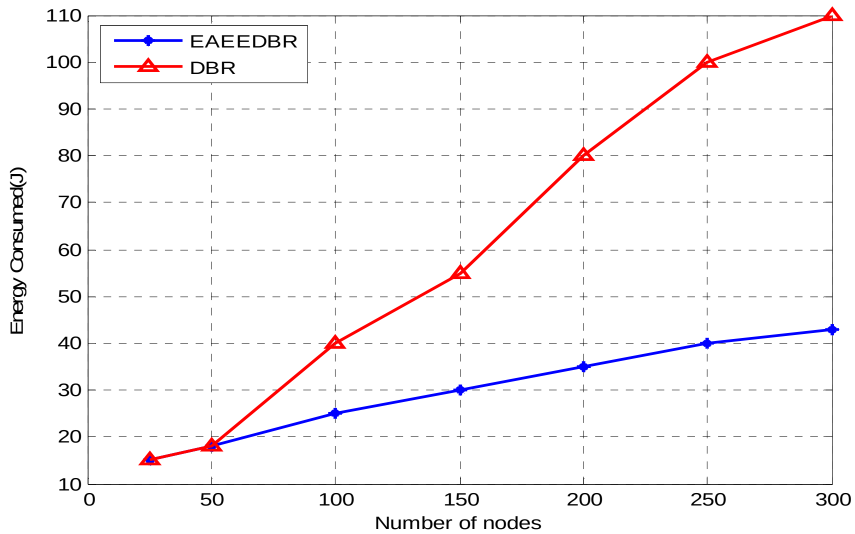

Fig. 3: Comparison of total energy consumption

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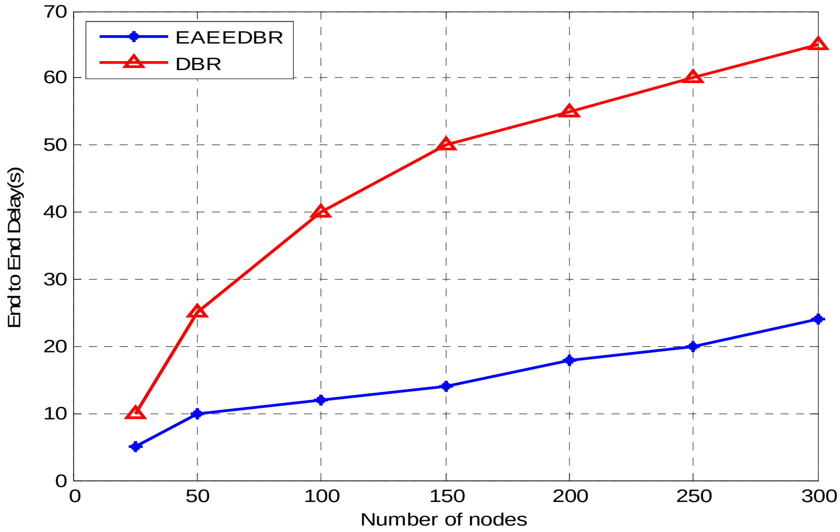

Fig. 4: Comparison of end-to-end delay

The average end to end delay of EAEEDBR and DBR in random topology is illustrated in Fig. 4. It may be observed that end to end delay is lesser in EAEEDBR. In DBR, each sensor node holds the packet for a certain time proportional to the depth of that sensor node. Thus DBR has a long average end-to-end delay. In contrast, in EAEEDBR, sender can forward the data packet based on locally discovering the most suitable neighboring sensor node. Therefore the delay is reduced only to the propagation delay of the packet. The delay in DBR is continuously increasing with the increase in network density because the number of forwarding nodes also increases with the increase in network density. The increase in network density does not affect the end-to-end delay in EAEEDBR because each time it chooses only one candidate senor node. The holding time in DBR is proportional to the depth. So, forwarding node has to wait for long time. On the contrary, the holding time in EAEEDBR is calculated based on the depth, residual energy and the distance from the sending node to the forwarding node which ensure the less time for a forwarding node to wait and separate holding time for each forwarding node.

The packet delivery ratio of EAEEDBR and DBR in random topology is illustrated in Fig. 5. It may be inferred from that in EAEEDBR, packet delivery ratio is slightly lower than that when compared with DBR. Only forwarding nodes with the highest priority always forward the packet in EAEEDBR unlike in DBR where many forwarding nodes forward the packet thus leading to higher delivery ratio of packets. Although redundant packet transmission does not take place in EAEEDBR, only the forwarding nodes with the high fitness always forward the packet, delivery ratio is a little bit less than that of DBR.

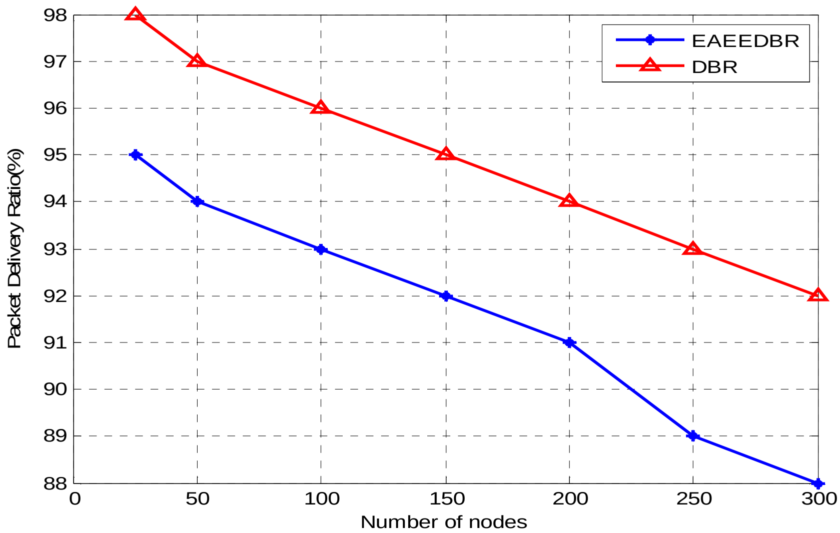

Fig. 5: Comparison of Packet Delivery

Conclusion:

In this paper, a novel Environment Adaptive Energy Efficient Depth Based Routing Protocol (EAEEDBR) for UWSNs is proposed and discussed in detail. The forwarding node always takes decision based on some important parameters such as variable sound velocity which is a very crucial parameter in three dimensional space and harsh underwater environment, residual energy, inter node distance and depth of the sensor nodes. To discover forwarding path, control packet is completely avoided in the protocol which is most necessary for meeting the challenges of UWSNs. It is inferred that EAEEDBR outperforms the existing Depth Based Routing protocol significantly in terms of network life time, average end to end delay and total energy consumption.

REFERENCES

Akyildiz, F., D. Pompili and T. Melodia, 2004. “Challenges for efficient communication in underwater acoustic sensor networks”,ACM Sigbed Review, 1(2): 3-8.

Ashrafuddin, M., M. Islam and M. Mamun-or-Rashid, 2013. "Energy Efficient Fitness Based Routing Protocol for Underwater Sensor Network," International Journal of Intelligent Systems & Applications, 5(2).

Guangzhong, L. and L. Zhibin, 2010. "Depth-based multi-hop routing protocol for underwater sensor network," in Proc. of 2nd International Conference onIndustrial Mechatronics and Automation (ICIMA), pp: 268-270.

Guo, L., P.H. Santschi, M. Baskaran and A. Zindler, 1995. “Distribution of dissolved and particulate in seawater from the gulf of mexico and off cape hatteras as measured by sims”, Earth and Planetary Science Letters, 133(1): 117-128.

Heidemann, J., Y. Li, A. Syed, J. Wills and W. Ye, 2005. “Underwater sensor networking: Research challenges and potential applications” ,USC/ISI Technical Report ISI-TR-2005-603.

Jafri, M., S. Ahmed, N. Javaid, Z. Ahmad and R. Qureshi, 2013. "AMCTD: Adaptive Mobility of Courier nodes in Threshold-optimized DBR Protocol for Underwater Wireless Sensor Networks," in Proc. of Eighth International Conference onBroadband and Wireless Computing, Communication and Applications (BWCCA), pp: 93-99.

Lee, U., P. Wang, Y. Noh, F. Vieira, M. Gerla and J.-H. Cui, 2010. "Pressure routing for underwater sensor networks," in Proc. of IEEEINFOCOM, pp: 1-9.

Noh, Y., U. Lee, P. Wang, B.S.C. Choi and M. Gerla, 2013. "VAPR: Void-Aware Pressure Routing for Underwater Sensor Networks,", IEEE Transactions onMobile Computing, 12(1): 895-908.

Rice., J.A., 2002. “Undersea networked acoustic communication and navigation for autonomous mine countermeasure systems” in Proceedings of the 5th International Symposium on Technology and the Mine Problem.

Wahid, A. and D. Kim, 2012. "An energy efficient localization-free routing protocol for underwater wireless sensor networks," International Journal of Distributed Sensor Networks,

Yan, H., Z. Shi, J.-H. Cui, 2008. "DBR: depth-based routing for underwatersensor networks", Ad Hoc and Sensor Networks, WirelessNetworks, Next Generation Internet, Lecture Notes in ComputerScience, 4982, Springer, Berlin, Heidelberg, pp: 72-86.