DCE2R: Distance Calculation Energy Efficient Routing Protocol for Underwater Wireless Sensor Network

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Summary
The research in the underwater environment is very interesting area for researchers due to its well know applications like: oil/gas, gold/silver information, ocean monitoring, valuable minerals, coal mining information etc. To extract the information from the seabed to sea-surface needs designing of routing, the designing of routing not the easy task for researchers due to environmental conditions of water like: water pressure, water current, underwater animal movements, 3-D deployment of the nodes, localization of nodes, prolong the battery power of the nodes, and uncontrollable node mobility. These all the issues affect the underwater routing for packets forwarding. This research article focuses the novel routing protocol by name Distance Calculation Energy Efficient Routing (DCE2R) for underwater wireless sensor network, which develops the efficient route through Distance Calculate Formula (DCF) and prolong the battery power of the nodes. The simulator NS2.30 with AquaSim is used for performance analysis and simulation results of the DCE2R has been compared with EE-DBR and EMGGR, from the simulation results DCE2R remained the well performer as compare to EE-DBR and EMGGR.

Key words:
WSSN; PGN; deployment; localization.

1. Introduction

Recently the Underwater Wireless Sensor Network (UWSN) is the main attractive area for researchers due to its well-known applications like: seismic monitoring, extract the information of the oil/gas, gold, minerals, coal mines from the bottom of the sea. Other applications like environmental monitoring, disaster preventions for coastal areas, scientific based applications, naval based applications etc [1-3].

UWSN is different in terrestrial wireless sensor network, because the deployment of the sensor nodes are easily in terrestrial network but the deployment of the nodes in underwater environment is complicated task due to underwater environmental conditions [4-6]. There are majority numbers of the issues has been addressed by the researchers for underwater environment like: to control the mobile nodes due to water pressure, to maintain the link quality between nodes, uncontrollable water depth, complicated charging of the nodes in underwater environment, and acoustic channel limitations [1, 7-9]. In underwater environment, we cannot prolong the battery power of the nodes and it is also complicated that battery cannot easily be recharged, because there is need of the electric power or ultraviolet light to charge the batteries of sensor nodes, so to charge the battery of sensor node is not so easy in harsh environment of the underwater [10-13]. In underwater environment, we are unable to use the radio frequencies (RF) because RF signaling has the limited range for packets forwarding and has also need of the large antenna which is not possible to deploy in underwater environment [14-16]. Fiber optical cable also cannot perform well in underwater environment because the light signaling cannot easily be travel in underwater dense environment. In underwater environment there is only the single source for the forwarding of the packets that is acoustic signaling [17, 18]. Acoustic signaling has the long propagation delay and acoustic signaling can forward the packets through sound waves [19, 20].

In UWSN, the majority number of routing protocols has been introduced which have resolved majority number of issues but still to develop the quality based link between nodes and maintain the power of battery is the major issues.

In this paper, we propose the Distance Calculation Energy Efficient Routing (DCE2R) protocol which maintains the link between nodes and can prolong the battery power of the nodes.

2. Related Work

There are majority number of the routing protocols has been introduced which maintains the link between nodes and can prolong the battery power of the nodes. The literature review for these protocols is mentioned in this section with its operation and limitations.

Power Efficient Protocol (PER) as mentioned in [21] is based on the fuzzy logic and tree trimming mechanisms, fuzzy logic mechanism is used to select the forwarder node for packets forwarding and tree trimming mechanism decides to forward packets in the developed route selection. In PER the forwarder node is unable to maintain the route

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due to the water pressure and the node may drop the data packets and cannot prolong the battery power. It is observed that the PER is unable to maintain the link quality between nodes or to prolong the battery power of the nodes because when forwarder node moves from its selected packets forwarding route due to water pressure, which affects the performance of the PER. There is no stable mechanism has been adapted by PER to maintain the battery power and develop the efficient link between nodes.

Energy Efficient Depth Based Routing (EEDBR) protocol is cited in [22], this protocol focuses two phase to maintain the link quality and prolong the battery power of the node, these phases are: knowledge acquisition phase and data forwarding phase. In knowledge acquisition phase the hello message is transferred to the nodes with smaller depth Id for developing the route. When route has been developed the packets may be forwarded to the sink nodes which are deployed at the water surface. In packets forwarding mechanism the residual energy of the nodes are checked and if any node have small energy then EEDBR not forward the packets to that node. It is observed from the simulation response of the EEDBR that this protocol cannot maintain its performance when network becomes sparse, even in sparse network the selected forwarder node can also drop the packets frequently and will die earlier.

Link-state Adaptive Feedback Routing (LAFR) protocol is mentioned in [23] focuses the asymmetric link mechanism with beam width communication range of 3600 for packets forwarding. It is observed from LAFR that the complicated data forwarding mechanism cannot show the better performance of the LAFR. It is also observed that no any stable mechanism is defined by LAFR to prolong the battery power of the nodes.

Multi-layer Routing protocol (MRP) protocol is defined in [10], is based on the formation of the layers around the static super nodes and layer ID formation mechanism is used by MRP to forward the packets to the lower to upper super nodes to sink nodes. The MRP has defined the 2D deployment mechanism in underwater environment where as underwater environment supports the 3D deployment mechanism. It is also observed from the simulation setup that MRP performs its simulation on NS2.34, which is not suitable for underwater environment.

Energy Efficient Depth Based Routing (EE-DBR) protocol is presented in [24], uses the multipath redundancy method to prolong the battery power of the sensor node. The distance measurement between nodes is based on Time of Arrival (ToA) technique. ToA measures the distance from forwarder node to the neighbor node, if distance increases the forwarder node will stop the packets forwarding. In EE-DBR the topology changes due to water pressure in seconds and it is observed that due to topology change the forwarder node may away from the selected route and will drop the packets.

Reliable and Energy Efficient Routing (REEP) protocol as mentioned in [25] adapted the same mechanism of ToA for finding the best path as given by [24]. REEP is based on network setup phase and transmission setup phase. In network setup phase, the selection of forwarder node is based on location information of the node with its residual energy. In REEP when route is selected the data transmission phase will transmit the data packets through multi-hop mechanism. It is observed from the REEP operation that, it only work on vertical data transmission, if network becomes sparse the overall performance of REEP becomes degraded and majority number of nodes will drop the packets and will die earlier.

Energy-efficient Multipath Grid-based Routing (EMGGR) proposed as mentioned in [26]. EMGGR is based on the formation of the 3D grids multipath mechanism. EMGGR focuses its operation for selection of three phases; one is gateway election method in the grid, second is updating the gateway with information mechanism, and third is data forwarding mechanism. For node which resides in cell will have xyz addressing mechanism with location information. The multipath route selection mechanism is adapted by EMGGR under which packets may be forwarded from source to virtual cell gateway node. The gateway nodes collect the data from virtual cells and forward that data to the sink nodes. The complicated grid formation and gateway election mechanism of EMGGR reduces the overall performance of the entire network. The gateway node may be move due to water pressure and will drop the packets and will die earlier.

Energy-efficient Distance Routing Protocol (DRP) is presented in [20] focuses the distance-varied collision probability method for selection of route. The smaller and larger vulnerability range method is used for nodes to calculate the inner and outer radius. DRP forwards the hello packet with residual energy parameter to the neighbor nodes to develop the routes. Through forwarder node the multipath disjoint method is adapted for packets forwarding. In DRP the distance may be increases due to the water pressure and forwarder node may become away from the selected route which drops the packets and will die earlier.

Cluster Based Energy Efficient Routing (CBE2R) protocol mentioned in [6] is based on formation of layers and formation of cluster based mechanism. CBE2R forwards the data packets through low weight value mechanism and use of courier nodes from source to sink node. CBE2R is unable to perform well when network becomes sparse. It is also observed that the cluster head of CBE2R drops the packets when it will away from the selected route through water pressure.

Reliable Multipath Energy Efficient Routing (RMEER) protocol is mentioned in [27] is also based on the formation of the multiple layers and multipath data forwarding mechanism. In RMEER the fixed courier nodes collects the data from source node through ordinary node which makes the multipath and forward that data through upper layer fixed courier nodes by utilizing of the maximum power levels to the sink node. It is observed that due heavy multipath selection mechanism of RMEER increases the average-end-to-end delay and multipath may be disturbed due to water pressure and forwarder node may drop the packets, which increases the overall energy consumption of the entire network.

3. Distance Calculation Energy Efficient Routing (DCE2R) protocol

In this section, we describe the complete operation of DCE2R protocol in detail. DCE2R is based on three phases: one phase focuses the architecture and deployment of the nodes, second phase focuses the route development phase, and third phase focuses the data forwarding phase. DCE2R is an energy efficient routing protocol which prolongs the battery power of the nodes through distance controlled mechanism.

In phase one, the architecture, and 3D deployment of the nodes are mentioned. The four kinds of nodes are deployed, sink nodes are placed on the surface of the water and are connected between each other through radio frequency signaling (RF). Water Surface Sink Nodes (WSSN) are responsible to collect the information from underwater nodes and forward that information to the onshore data center, which also connected with WSSN nodes through RF signaling. Underwater depth is divided into two parts; one is upper depth and second is lower depth. In upper depth we have deployed Power Generator Nodes (PGNs) with limited number, the PGNs has more power as compare to other nodes and also prolongs the much more battery power in underwater environment. PGNs are dynamic 3D deployment nodes which can control the horizontal and vertical movement with dense and sparse area network. Deployment of PGNs node enhances average consumption of the entire network.

In higher depth the two more types of the nodes are deployed, one Packets Forwarder Nodes (PFNs) and others are Packets Collector Nodes (PCNs). PFNs are ordinary nodes which collects the data packets from the PCNs and relay that data to the PGNs by calculating the shortest route development mechanism. PCNs are responsible to collect the application based information from the bottom of the sea and forward them to the PFNs.

Every PCNs which are deployed at seabed can collects the packets from seabed and can simultaneously forward the packets to the relevant PFNs to PGNs and to WSSN. The DCE2R architecture is shown in Fig. 1.

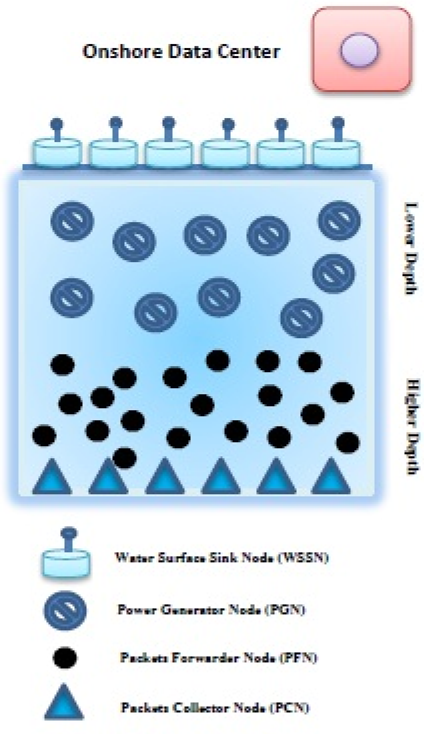

Fig. 1 DCE2R architecture

In route development phase, the route is developed between PCNs nodes to PFNs nodes to PGNs to WSSN. Every PCNs will forward the route selector format to the PFNs with fields of as mentioned in Fig. 2.

PCN-ID	PFN-ID	PGN-ID	DCF	R_Energy

Fig. 2 Route Selector Format

The description of the following fields is mentioned below:

(i) PCN-ID field consumes the 2 bytes and hold the address of PCN.

(ii) PFN-ID field also consumes the 2 bytes and hold the address of PFN.

(iii) PGN-ID consumes the two bytes and holds the address of the relevant PGN.

(iv) DCF is the Distance Calculation Formula between nodes which consumes the 2 bytes and hold the calculated distance between PCNs, PFNs, and PGNs. The PCN will develop the route on calculation of the shortest distance. The DCF is mentioned in Equation (1).

DCF= Distance + number of hops + Residual Energy (1)

Distance is measured in meters/kilometers, number of hops means minimum number of hops from PCN to PFN to PGN to WSSN, and Residual Energy focuses the remaining residing energy of the node from its initial energy.

(v) R-Energy field consumes the two bytes memory and will look the remaining energy level of the node.

It is noted that if the energy level of any node will remain 20% of the initial energy then that node will not be selected for the route. PCN node forwards the Route Selector Format (RSF), to every nearby PFN and will wait for ACK. During route selection PFNs and PGNs also shares the ACK. The route selection mechanism is shown in Fig. 3.

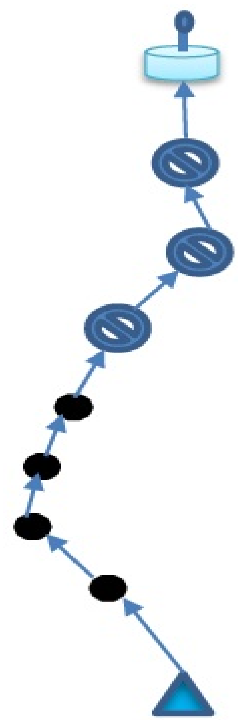

Fig. 3 Shortest Route Development for DCE2R

Fig. 3, focuses the shortest energy efficient route development from PCN to PFNs to PGNs to WSSN through DCF. When route has been development, DCE2R will forward the packets from seabed to water surface and will qualify the data forwarding phase.

4. Performance analysis of DCE2R

For performance analysis the NS2.30 with AquaSim simulator is used, the simulation parameters are shown in Table 1.

Table 1: Simulation Setup for NS2.30

SNo	*Parameter*	*Values*
1	Simulator	NS2.30
2	Total No. of Nodes	350
3	Topology	Random
4	Deployment	3D
5	Network Size	1500x1500x1500
6	Transmission range	250m
7	Initial Energy	70 J
8	Packet size	64 bytes
9	MAC layer Protocol	802.11-DYNAV
10	Simulation time	1000 Secs

In performance analysis DCE2R is compared with EE-DBR and EMGGR routing protocols through data success ratio, network throughput, average energy consumption, end-to-end delay, and network lifetime.

4.1. Data Success rate

Data Success rate can be measured the packets transferred from the PCNs and packets received by WSSNs. The Data Success Rate is shown is Fig 4.

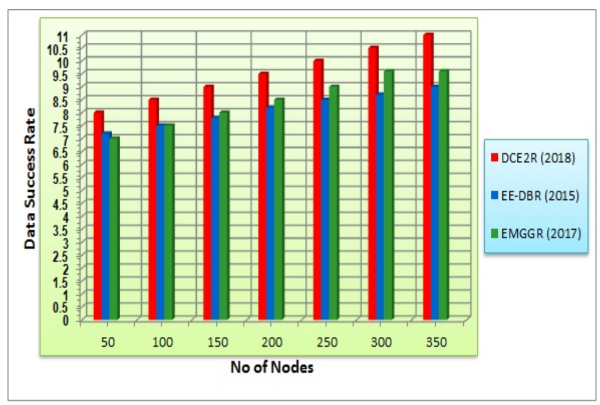

Fig. 4 Data Success Rate for DCE2R over EE-DBR and EMGGR

The data success rate of DCE2R is higher than EE-DBR and EMGGR, because DCF calculates the shortest distance and forwards the packets through shortest distance. The data success rate of EMGGR is higher than EE-DBR because EMGGR is based on multipath data forwarding method. On other hand EE-DBR data success rate is lower than DCE2R and EMGGR because the ToA and distance measured method is not functioning well when network becomes sparse.

4.2. Network throughput

Network throughput is measured in kilobits per second and is the received packets of entire network on the surface WSSN. The network throughput of DCE2R is shown in Fig 5.

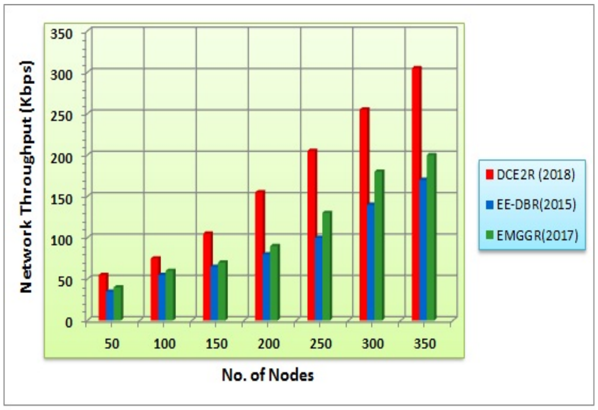

Fig. 4 Network throughput for DCE2R over EE-DBR and EMGGR

The network throughput of DCE2R is higher than EMGGR and EE-DBR because the use of PGNs. PGNs are the powerful nodes and enhances the network throughput of DCE2R. On other hand the complicated gateway election mechanism of EMGGR and formation of variable grids reduces the network throughput. It is observed that the network throughput of the EE-DBR is lower due to uncontrollable node mobility.

4.3. Energy Consumption

Energy Consumption of DCE2R is lower than EMGGR and EE-DBR because the power use of PGNs and residual energy threshold up to 20% prolongs the battery life of the DCE2R protocol. The EMGGR is unable to control the node movement when network becomes sparse and in resultant the overall energy consumption of entire network is higher than DCE2R. The energy consumption of EE-DBR also faces the same issue due to uncontrollable forwarder node when network becomes sparse.

4.4. End-to-End Delay

The end-to-end delay is defined the delay of arrival of packets at the WSSN from all the sources. The end-to-end delay for DCE2R is shown is Fig. 5.

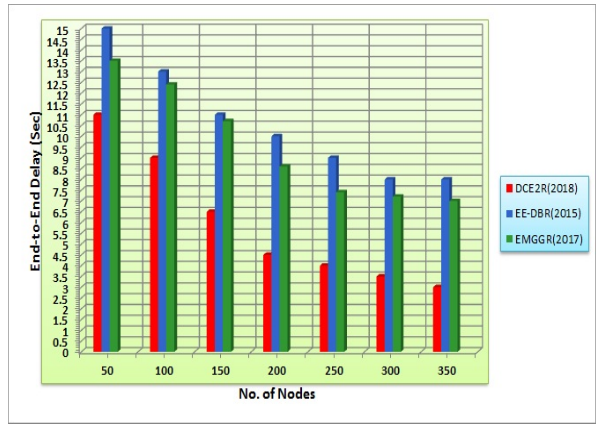

Fig. 5 End-to-End delay for DCE2R over EE-DBR and EMGGR

The end-to-end delay for DCE2R is lower than EMGGR and EE-DBR because DCE2R refers the powerful PGNs and link quality based route through DCF. On other hand the end-to-end delay of EMGGR is lower than EE-DBR because the selection of grid approach and gateway election mechanism is the stable mechanisms as compare to EE-DBR.

4.5. Network lifetime

The network lifetime focuses the die of any node due to the energy depletion. The network lifetime of DCE2R is shown in Fig. 6.

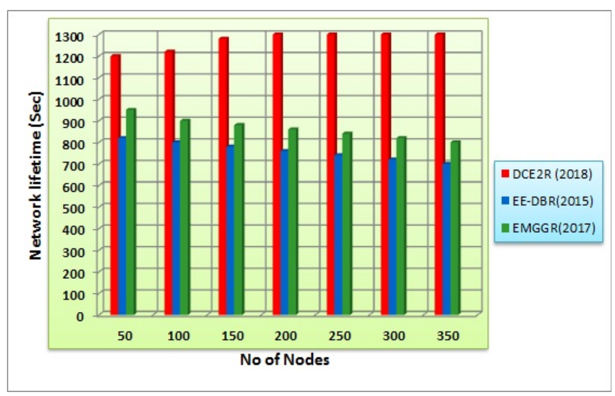

Fig. 6: Network lifetime for DCE2R over EE-DBR and EMGGR

The network lifetime of DCE2R is higher than EMGGR and EE-DBR because due to major number of PGNs are used because due PGNs powerful node, the network lifetime remained high. On other hand the network lifetime for EMGGR is higher than EE-DBR because the grid mechanism and gateway election mechanism keeps the network lifetime higher than EE-DBR. EE-DBR cannot perform well when network becomes sparse.

5. Conclusion

This research article focuses the Distance Calculation Energy Efficient Routing (DCE2R) protocol. DCE2R is robust and energy efficient routing protocol which prolongs the battery power of the nodes through the selection of PGNs and stable route development mechanism. DCE2R forwards the packets to those PFNs or PGNs which keeps the energy level 20% of the initial energy. DCE2R is based on three phases, phase one focuses the generic architecture with deployment of nodes in upper and lower depth of the water. The four kinds of nodes are used in DCE2R, the WSSNs nodes are deployed on the water surface and collects the data packets and forward the packets to onshore data center. PGNs are the powerful nodes and are deployed in upper depth in 3-D deployment mechanism. PCNs are deployed at the seabed level which collects the packets and forward those packets to the PFNs and PFNs forward the packets to the PGNs. Second phase focuses the route development phase through DCF, the energy-efficient shortest route has been developed to forward the packets to the surface WSSNs. Packets forwarding mechanism is the third phase of DCE2R. From simulation performance the DCE2R performed well as compare to EE-DBR and EMGGR.

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