LWDE2R: Low Weighted Distance Energy Efficient Routing Protocol for Underwater Wireless Sensor Network

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Summary
Deployment in underwater wireless sensor network is the major issues because underwater environment supports the 3D deployment, deployment can be affected due to the environmental conditions of the water like: water pressure, water current, acoustic channel limitations, biological conditions of the water, and underwater animal movement. In underwater environment depth controlling with long distance is also the major issue, underwater depth controlling the batteries of the nodes needs proper attentions because in underwater environment the sensor nodes cannot easily be recharged, so to prolong the battery power in underwater environment needs special mechanism to prolong the battery power of the nodes. To resolve such kind of issues the Low Weighted Distance Energy Efficient Routing (LWDE2R) is proposed. LWDE2R prolongs the battery power of the nodes through use of static courier nodes and efficient data forwarding mechanism. LWDE2R also controls the depth of the water as compare to existing routing protocols. For performance analysis, NS2.30 simulator is used. The results of LWDE2R are compared with CVBF, MCCP and DUCS, and from simulation analysis the performance of LWDE2R is higher than CVBF, MCCP, and DUCS.
Key words:
Low-weight; courier-node; distance; water-depth

1. Introduction

Underwater environment comprises the many more applications for research attentions in research community, these applications are: tactical surveliance, assisted navigation, disaster prevention, assited navigations, pollution monitoring, offshore exploration, and oil/gas, gold, minerals, diamond based applications [1-3]. In underwater environment the design of routing protocol faces many challenges like: the limited bandwidth for data forwarding, acoustic channel is affected with the multipath fading, propagation delay due to behavior of the acoustic channel, packets may be drops due to shadow zones, underwater connectivity problem between nodes due underwater pressure, batteries of sensor nodes can not easily be recharged, any many more problems [4-7]. From also these issues the major issues which needs attention are: to prolong the battery power of the nodes, control the water depth, and develop the efficient link between nodes for data forwarding. The majority number of routing protocols are designed to resolve these special kind of issues but still research needs enhancement. This research article introduces the design of Low Weighted Distance Energy Efficient Routing (LWDE2R) which controls the water depth, develops the energy efficient route between nodes, and prolongs the battery power of the nodes. The operation of LWDE2 is mentioned in section 3.

2. Related Work

In this section the related energy efficient roting protocols are defined with their operations and limitations.

Minimum-Cost Clustering Protocol (MCCP)

Minimum-Cost Clustering Protocol is mentioned in [8]. MCCP is comprising three parameters to resolve the energy issue, total energy consumed by memebr node and clusted head node, residual energy for cluster head and cluster member nodes, and location between cluster head and sink nodes [9]. MCCP uses the load balacing mechanism in between cluster head nodes and cluser member nodes. It is observed from the operation of the MCCP that there is no proper mechanism is used to prolong the battery power of the nodes.

Dstributed Underwater Clustering Scheme (DUCS)

DUCS is proposed in [10], this routing protocol is GPS free and depends on data aggregation mechanism. Authors of the DUCS claimed that node mobility is fully controlled through consideartion of TDMA/CDMA mechanisms. DUCS improves the quality in communication. For DUCS there is no proper mechanism for depth controlling is used, in DUCS no any suitable energy model is used.

Link-state Adaptive Feedback Routing (LAFR)

LAFR is proposed in [11], in this routing protocol the asymmetric link mechanism is udes to develop the efficient link between nodes to prolong the battery power of the nodes. For data forwaridng mechanism beam width communication range for 3600 is used. LAFR uses the

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claculation mechanism for asymmetric link and beamwidth puts the extra load on the nodes and node will deplete its energy very soon and cannot show the good performance regarding energy consumption.

Clustered Vector Based Forwarding (CVBF)

In [12] CVBF routing protocol is defined. CVBF makes the predeined cluster formation of the entire network. Inside the cluster the routing mechanism as adapted from Vector Based Forwarding (CVBF). CVBF is single sink architecure protocol. The vector based forwarding algorithm is adapted by CVBF to improve the performance. It observed from the simulation response of the CVBF that the performance analysis of this routing protocol is not reasonable because CVBF has adapted the same data forwarding mechanism of VBF. It is also observed that no proper energy saving algorithm is used to prolong the battery life of the nodes.

Multi-layer Routing Protocol (MRP)

MRP is proposed in [2], in this routing protocol the use of super node is adpted to prolong the battery power of the sensor node. For data forwarding the layer formation around super node with layer-Id is used. MRP controls the depth by dividing the water depth into upper and lower depth. It is observed that when network becomes sparse the performance of the MRP is not seem to be well.

Energy Efficient Depth Based Routing (EE-DBR)

EE-DBR is proposed in [13]. This routing protocol saves the energy of the nodes through use of distance ranging technique, EE-DBR observes the distance and if distance increases beyond the limit, EE-DBR will stop for packets forwarding. For data forwarding EE-DBR refers the Time of Arrival (ToA) technique. EE-DBR is unable to control the water depth. It is also observed that if increased distance remain long time the overall performance of the EE-DBR remain affected.

Reliable and Energy Efficient Routing (REEP)

EEP is propose in [14]. In this routing protocol ToA technique is used to find the best availble path for data forwarding. In REEP the measured distance is used to prolong the battery power of the nodes. The REEP has adapted the EE-DBR mechanism, and REEP has also seem limitations as described in EE-DBR.

Energy-efficient Multipath Grid-based Geographic Routing (EMGGR)

EMGGR is proposed in [15]. In this routing protocol the 3D grids are formed in underwater environment. In grid formation the every cell comprises it xyz addressing mechanism. For packets forwarding the multipath between source (gateway) to sink through virtual cell nodes is used. EMGGR prolongs the battery power of the nodes through selection of virtual cell. It is observed that no depth controlling mechanism is adapted by EMGGR. Even grid formation mechanism is complicated specially in umderwater environment.

Energy-efficient Distance Routing (DRP)

DRP is proposed in [16]. In this routing protocol the distance varied collision probability mechanism is used for efficient route selection. DRP look the residual energy of each node along efficient route selection to prolong the battery power of the nodes. DRP refers the multipath route selection mechanism for data forwarding. It is observed that DRP is unable to prolong the battery power of nodes because this routing protocol is based on limited covering area, if the area is increased the performance of the DRP remains not reasonable.
From aforementioned routing protocols it is observed that existing routing protocols are unable to control the water depth, no proper mechanism is defined to prolong the battery power of the nodes. The efficient route selection mechanism is also needed to enhance the performance interms of network throughput, network lifetime, and data success ratio.

3. Low Weighted Distance Energy Efficient Routing (LWDE2R) protocol

LWDE2R protocol is designed to prolong the battery power of the nodes, develops the efficient route selection mechanism and controls the water depth from sea-surface to seabed. The deployment with data forwarding mechanism is shown in Fig. 1, the sink nodes are deployed on the sea-surface, the water depth is divded into seven layers from sea-surface to seabed, on every layer the static powerful courier nodes are deployed, source nodes are deployed at seabed level and are able to extarxt the valuable data from the bottom of the sea. Ordinary nodes are deployed in between layer-7 to source nodes. The multipath node disjoined method is used for selection of energy efficient route. Fig. 2., focuses the data forwarding model under which the energy efficient route has been selected.

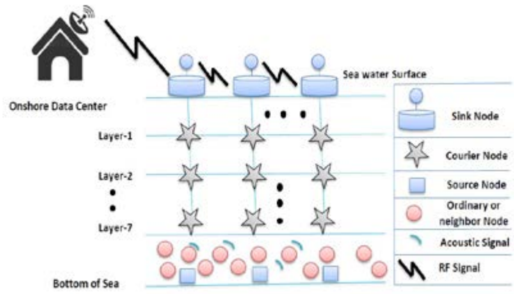

Fig. 1 LWDE2R network model

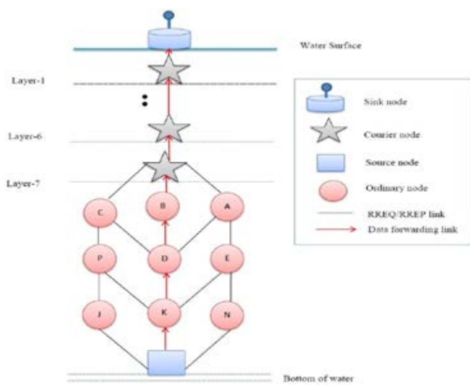

Fig. 2 LWDE2R Data forwarding Model

The route selection mechanism is based on Low Weighted Distance (LWD) which is shown in Equation 1. The route development mechanism is start by RREQ and RREP mechanism. If source node has a data then source node will forward the RREQ format to all theordinary nodes to develop the multipath. RREQ format has following fields.

i. Source node id: this consumes the two bytes and will show th relevant address of the source node.
ii. Forwarder node id: this consumes the two bytes and holds the id of the neighbour node or forwarder node.
iii. LWD field: this field consumes the four byte and assigns the calculated LWD as shown in Equation 1.
iv. Courier Node id: This field consumes the 2 bytes and keeps the address of the relevant layer-7 courier node.

When courier node will receive the RREQ, the courier node will observe the low weighted distance route and on that route will RREP to the source node, when source node will receive the RREP then source node will forward the packets along to energy efficient route. The complete route selection mechanism is described in “Route assigning and selection example” as mentioned below.

$$LWD = D\ Distance + Re\ \ Residual\ Energy + Hc\ \ hop\ count \quad (1)$$

Route assigning and selection Example

i. $LWD_{\ Total}$ *= Source → N→ E → A → Courier = 62*
[Separate LWD: Source to N = 10, N to E = 20, E to A = 25, A to courier = 7]
[$LWD_{\ Total}$ *= 10+20+25+7=62]*

ii. $LWD_{\ Total}$ *= Source → K→ D → B → Courier = 40*
[Separate LWD: Source to K = 8, K to D = 16, D to B = 8, B to courier = 8]
[$LWD_{\ Total}$ *= 8+16+8+8=40]*

iii. $LWD_{\ Total}$ *= Source → J→ P → C → Courier = 59*
[Separate LWD: Source to J = 15, J to P = 20, P to C = 25, C to courier = 9]
[$LWD_{\ Total}$ *= 15+20+25+9=62]*

iv. $LWD_{\ Total}$ *= Source → K→ P → C → Courier = 55*
[Separate LWD: Source to K = 16, K to P = 18, P to C = 12, C to courier = 9]
[$LWD_{\ Total}$ *= 16+18+12+9=55]*

v. $LWD_{\ Total}$ *= Source → K→ E → A → Courier = 50*
[Separate LWD: Source to K = 10, K to E = 15, E to A = 20, A to courier = 5]
[$LWD_{\ Total}$ *= 10+15+20+5=50]*

vi. $LWD_{\ Total}$*= Source → K→ B → A → Courier = 57*
[Separate LWD: Source to K = 13, K to B = 17, B to A = 20, A to courier = 7]
[$LWD_{\ Total}$ *= 13+17+20+7=57]*

vii. $LWD_{\ Total}$ *= Source → K→ B → C → Courier = 68*
[Separate LWD: Source to K = 15, K to B = 25, B to C = 20, C to courier = 8]
[$LWD_{\ Total}$ *= 15+25+20+8=68]*

From the example it is clear that : $LWD_{\ Total}$ = Source → K→ D → B → Courier = 40 is the lowest distance route and source node will forward the packets along this route. Layer-7 courier nodes receives the packets through ordinarary nodes on energy efficient route, the courier node will utilize maximum power level to relay the packets to the sink nodes through other layered courier nodes.

4. Performance Analysis

The performance of LWDE2R is measured in terms of network throughput (Kbps), Network lifetime (sec), Total energy consumption (joules), average end-to-end delay (sec), and packets delivery ratio (%). The simulator

NS2.30 is used for performance analysis. The simulation setup paramets are shown in Table 1.

Table 1: NS2.30 simulation setup

Parameters	Values
Network Size	1500m x 1500m
No. of Nodes	350
Surface to bottom layer distance	250m
Data Packet size	64 byte
Initial Energy	70 J
MAC Protocol [17]	802.11-DYNAV
Routing Pipe in VBF	100 m
Energy consumption for transmitting	2w
Energy consumption for receiving	0.75w
Energy consumption for idle listening	8mw
Energy Threshold	20% of initial
Transmission range	100 m to 150 m
Surface sink distance difference	100 m
Number of layers	7
Number of courier nodes	49
Simulation time	1000 sec

In this section we compare the simulation results for performance metrics of our proposed routing protocol with routing protocols like CVBF, MCCP, and DUCS. In Fig. 3; the throughput in Kbits/sec versus number of nodes is shown with 50, 100, 150, 200, 250, and 350 numbers of nodes. The throughput of LWDE2R is higher than CVBF, MCCP, and DUCS because in LWDE2R we used the powerful fixed courier nodes on different layers which enhance the network throughput.

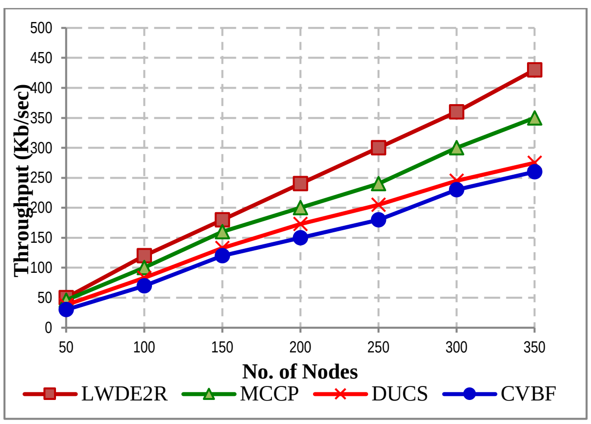

Fig. 3 LWDE2R Throughput versus No. of nodes

The network lifetime is shown in Fig.4. The network lifetime of LWDE2R is also higher than CVBF, MCCP, and DUCS. The uses of the high power static courier nodes on different layers have enhanced the life of the ordinary sensor nodes and ultimately the result focuses the good response in network lifetime of the LWDE2R protocol as compare to other proposed routing protocols. In LWDE2R the courier nodes have abundant energy. Since these courier nodes forward the data packets, long network lifetime can be expected. Additionally the use of low weighted distance mechanism for LWDE2R also enhances the network lifetime.

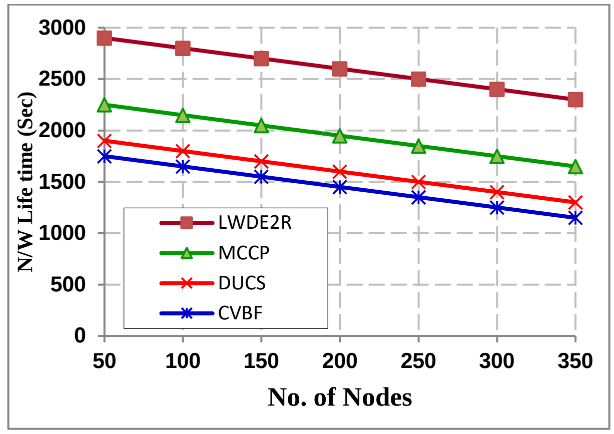

Fig. 4 LWDE2R N/W Lifetime versus No. of nodes

Total energy consumption measured in joules is shown in Fig. 5. The LWDE2R protocol has used the low weighted distance and energy efficient route selection and the use of the courier nodes have enhanced the life of the ordinary sensor nodes. In Fig. 5, the LWDE2R consumes the less energy as compare to CVBF, MCCP, and DUCS.

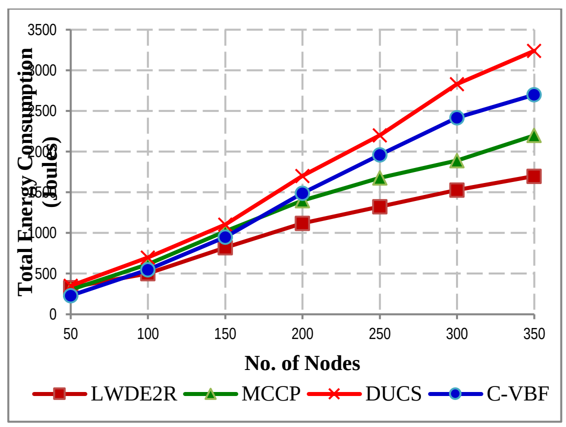

Fig. 5 LWDE2R Total Energy Consumption versus No. of nodes

Fig. 6, focuses the average end-to-end delay. In Fig. 6, we observed that the average end-to-end delay of LWDE2R is low as compare to CVBF, MCCP, and DUCS because the uses of courier nodes with maximum power levels have resolved the problem of average end-to-end delay. In Fig. 6, it is clear that LWDE2R utilizes less time (sec) to forward packets to the sink nodes as compare to other routing protocols.

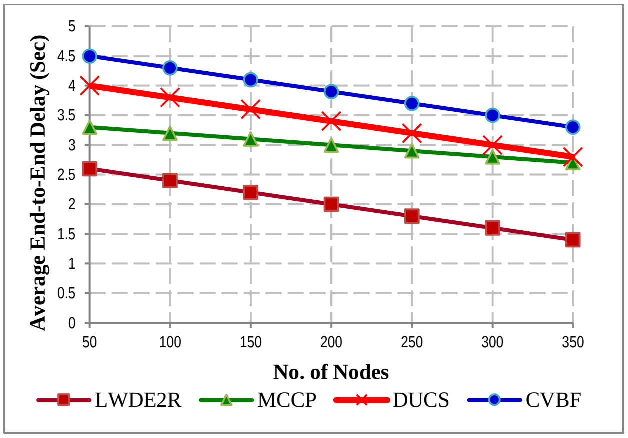

Fig. 6 LWDE2R Average End-to-End delay versus No. of nodes

Packets delivery ratio is shown in Fig. 7. The packets delivery ratio is measured the packets forwarded by source nodes and packets received by the sink nodes. Fig. 7, focuses that the packets delivery ratio of LWDE2R is higher as compare to LWDE2R. In LWDE2R the use of powerful courier node and use of low weighted distance enhances the packets delivery ratio.

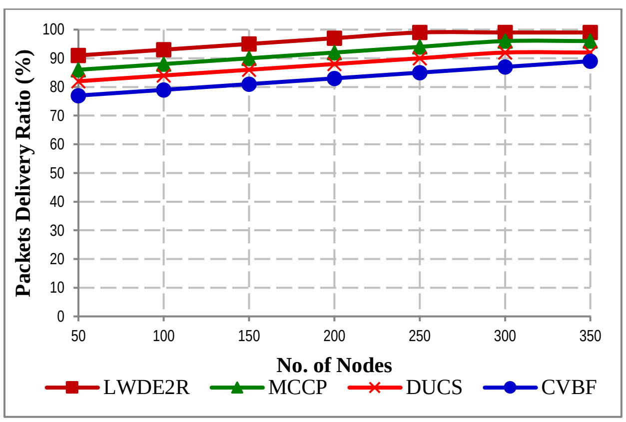

Fig. 7 LWDE2R Packets Delivery Ratio versus No. of nodes

5. Conclusion

This research article focuses the Low Weighted Distance Energy Efficient (LWDE2R) routing protocol, the proposed routing protocol resolves the three major issues. LWDE2R resolves the water depth issue through use of layer formation mechanism. LWDE2R prolongs the battery power of the nodes through use of static powerful courier nodes and LWD route selection mechanism. LWDE2R forwards the data packets from source to sink node through low weighted distance with controlling of node mobility in efficient way. LWDE2R uses the NS2.30 simulator for performance analysis and it is observed that the performance of LWDE2R is better as copare to CVBF, MCCP, and DUCS.

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