A Survey on Link Quality Based Routing Protocols for Underwater Wireless Sensor Network

Mukhtiar Ahmed[1], Sajida Parveen[2], Nazar Hussain[3], Nadeem Naeem[4], Rajab Malookani[5]

Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Sindh, Pakistan[1,2,3,4,5]

Summary
This research article focuses the link quality based routing protocols for underwater wireless sensor network. In this article the novel classification of link quality based routing protocols is presented with protocols' operation to maintain the link between sensor nodes. Method/analysis is based on performance of the link quality based routing protocols which are further classified into vector-based, depth-based, and energy-saving link quality based routing protocols. The protocols' operations with its limitations are presented in this article. From the operation of the link quality based routing protocols the findings are based on parametric comparative analysis and numerical simulation based analysis, which is the novel contribution of this research article. This research article helps the researchers to further work in the maintenance of link between sensor nodes to enhance the overall packets delivery ratio.

Key words:
link-quality, water-depth, energy-saving, battery-power, seabed

1. Introduction

The research in underwater environment is the well interesting area for the researchers due to its well-known applications like: coal mines, gold, silver, oil and gas, seismic monitoring, naval based applications etc [1-5]. To extract the information from the seabed and to forward that information towards sea surface needs the link quality based routing [6]. In underwater environment the link quality based routing is the complicated task for the researchers due to underwater harsh environment, water pressure, water current, and long distance from sea surface to seabed. Water pressure develops the node mobility during route develops between the nodes, due to the node mobility the route broken immediately and in resultant the packets may drops and will degrade the overall network throughput. Majority of the authors have resolved the problem to develop the link between nodes to forward the packets in efficient way but still link quality needs improvements[7-10]. The novel contribution of this research article is mentioned below:

i. This research article focuses the link development methods of the protocols.
ii. This research article classifies the novel link quality based routing protocols' classification.
iii. This research article focuses the latest gap for designing of new routing protocol based on link quality.
iv. This article focuses the new parametric comparison between protocols.
v. This article focuses the numerical simulation method for comparison.

2. Related work

Related work is based on the novel classifications of the link quality based routing protocols which is shown in Fig. 1.

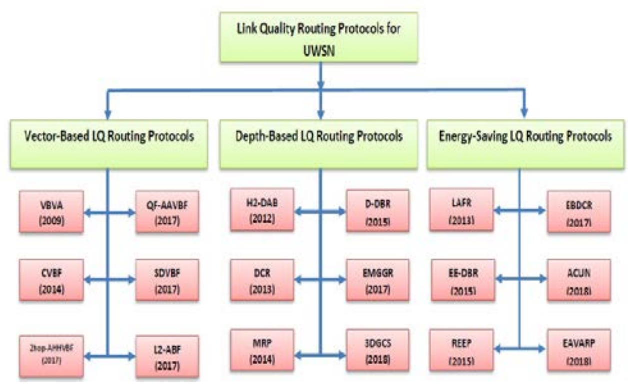

Fig. 1 Classification of Link quality based routing protocols

Vector-Based Link Quality Routing Protocols

The vector-based link quality routing protocols refers the routing pipe radius to maintain the link quality in between nodes. To control the link quality between nodes the following protocols uses the different methodology.

Vector-Based Void Avoidance (VBVA)

VBVA routing protocol is specially designed to remove the void regions for the data forwarding path [11], but it follows the methodology to improve the link quality between nodes. VBVA uses the vector-shift and back-

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pressure mechanism for removal of void regions during packets forwarding. VBVA follows the vector pipe radius to forward the packets from source to sink node which is deployed on the water surface. VBVA follows the performance mechanism of VBF [12]. It is observed that when network becomes sparse the performance of the VBVA becomes very slow.

Clustered Vector-Based Forwarding (CVBF)

CVBV is based on the formation of multiple vector pipe clusters to forward the data packets from source to sink node [13]. CVBF follows the same rule for data forwarding as defined by VBF, however the performance of CVBF is better as compare to VBF because of multiple clusters with controlling of node movement. It is also observed that the limited area for vector pipes reduces the overall performance of the CVBF.

Two hop adaptive vector based forwarding (2hop-AHH-VBF)

2hop-AHH-VBF follows the same method for data forwarding as defined by VBF [14]. 2hop-AHH-VBF specially designed for the removal of the void regions in sparse area network. The authors claimed that the 2hop-AHH-VBF removes the void holes in efficient way and reduces the end-to-end delay but the mechanism adapted by authors is only for sparse network which is not suitable for VBF because VBF is purely designed for dense area network.

Quality forwarding adaptive hop by hop vector-based forwarding (QF-AHH-VBF)

QF-AHH-VBF is based for the selection of the optimal forwarding adaptive hop by hop priority in mechanism to controls the holes in underwater environment [15]. It reduces the void holes probability through optimal node forwarding with next hop. The authors claimed that through this mechanism they enhance the overall network throughput. From the mechanism which is adapted by authors is not suitable when network becomes sparse.

Spherical Division Vector Based Forwarding (SD-VBF)

SD-VBF divides the routing pipe (cylindrical) after applying the spherical division (SD) to minimize the energy consumption of the nodes [16]. The SD-VBF has adapted the methods for packets forwarding from VBF and VBF itself is based on limited region and is failure to maintain the node mobility when network becomes sparse or dense.

Layer-by-Layer Angle Based Flooding (L2-ABF)

The data forwarding mechanism of L2-ABF follows the VBF although the authors recommended this protocol’s functionality for sparse and dense network with flooding based approach [17]. The authors compare the simulation response of this protocol with DBR but due to small interest area the performance of this protocol is not reasonable.

Depth-Based Link Quality Routing Protocols

These kind of routing protocols are based on depth controlling mechanisms from sea surface to sea bottom. The following routing protocols have described the different methods for controlling of the depth.

Hop-by-Hop Depth Addressing Based Routing (H2-DAB)

H2-DAB has used the dynamic addressing mechanism for controlling of the depth from sea surface to sea bottom [18]. In H2-DAB every node in the network is assigned with the unique address to route the packets. The addressing mechanism is based on explicit dimension location information for the nodes. When every node goes up then that node will be assigned by the new depth address. H2-DAB addressing mechanism is failure when network become sparse.

Depth Controlling Routing (DCR)

DCR is designed to control the depth only for void regions. The authors of the DCR claimed that this protocol controls the dynamic topology in underwater environment but unfortunately they have not properly defined the mechanism of the topology control. DCR has used the sonoboys and beacons for next hop node selection to forward the packets. It is observed from the simulation responses that DCR is failure to prolong the battery power of the nodes when network becomes dense.

Multi-layered Routing Protocol (MRP)

MRP has divided the water depth in different layers and assigned the different addressing mechanism to every layer [19]. MRP is based on static super node in lower and higher depth layers to prolong the network lifetime. Super node collects the packets and forwards them to sink nodes. It is observed that the MRP is only based on limited area and are unable to overcome the node mobility controlling mechanism.

Directional Depth Based Routing (D-DBR)

D-DBR controls the link between nodes through ToA and angle controlling mechanisms between forwarder nodes [20]. It observed from the data forwarding mechanism that

D-DBR only controls the dense are network, when network becomes sparse D-DBR is failure to show the reasonable performance.

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

EMGGR forms the 3D grids to control the water depth [21]. The authors have used the multipath data forwarding mechanism for elections of gateways in the cells to forward the packets. It is observed that the election of gateway mechanism is time consuming which reduces the overall performance of the network.

3D Grid Clustering Scheme (3DGCS)

This routing scheme is based on optimal and local balanced formation of clusters on each 3D grids to forward the data packets to the relevant cluster heads [22]. The authors of this routing scheme claimed that due to grid mechanism, the water depth is fully controlled but from its simulation response the overall performance of this routing scheme is not reasonable.

Energy-saving Link Quality Routing Protocols

Majority of the researchers have defined the majority of the algorithms for the saving of energy of the nodes but still research needs improvement. The following routing protocols have used different energy saving mechanisms.

Link-state adaptive routing (LAFR)

LAFR routing protocol is based on asymmetric link method and beam width with range of 3600 to balance the energy of the nodes in underwater environment [23]. The use of angle calculation mechanism for node puts down the heavy load on the nodes under which the node will become exhausted and will die earlier.

Energy Efficient Depth Based Routing (EE-DBR)

EE-DBR uses the multipath redundancy method to prolong the battery power of the nodes [20]. EE-DBR is based on the geometrical model to forward the forwarder node. The forwarder model is focused on the defined region, if forwarder node has packets and due to water pressure if this node becomes sparse the node will not come under the defined region and in resultant node will drop the packets continuously and will die earlier.

Reliable and Energy Efficient Protocol (REEP)

REEP follows the traditional approach as calculation of residual energy to prolong the battery power of the node [24]. The residual calculation mechanism is based only on the vertical movement of the node; if node becomes horizontal then this kind of calculation becomes failure.

Energy-Balanced and Depth Controlling Routing (EBDCR)

EBDCR is based on the replacement of the low energy level nodes with respect to the depth adjustment mechanism [25]. The authors have suggested the replacement of the low energy nodes with high energy nodes which is not so simple in underwater harsh environment. It is also observed that the depth adjustment mechanism of EBDCR is not focused properly.

Energy-efficient multi-level adaptive clustering routing (ACUN)

ACUN is an algorithm of routing to prolong the life of the node through residual energy calculation mechanism and distance between clustered head and the sink nodes [26]. The determination for the size of the competition radius, if cluster head node is away from the sink node and cluster head shows the excessive competition radius that node will be selected for forwarding mechanism. ACUN is only based on the hypothesis, the real time parameters of the underwater environment seem to be the beyond of ACUN.

Energy-Aware and Void Avoidable Routing Protocol (EAVARP)

EAVARP is based on two phases to save the energy level of the nodes, phase one layering phase and phase two is data collection phase[5]. For development of the layers (shells) and data collection the opportunistic directional forwarding strategy (ODFS) has been adapted by EAVARP. ODFS looks the remaining energy level of the nodes within the shells, if the energy level of the node is less than ODFS then node will stop the re-transmission of packets.The shell formation mechanism of the EAVARP is not so easy in underwater environment.

3. Parametric Performance Analysis

Through parametric performance analysis we have chosen the different parameters to show the performance analysis of link quality routing protocols, which are defined in Table 1, Table 2, and Table 3.

Table 1: Parametric performance analysis of Vector-Based LQ Routing Protocols

S_No	Routing Protocol	Year	Node mobility Controlled	Hop-by-hop/end-to-end	Single/ Multiple Sink	Multipath	Hello/ Control Packet	Mechanism used
1.	VBVA	2009	No	Hop-by-hop	Single Sink	No	Yes	Vector shift & Back-pressure
2.	CVBF	2014	No	Hop-by-hop	Single Sink	No	No	Adaptive Mobility Depth-based
3.	2hop-AHHVBF	2017	No	Hop-by-hop	Single Sink	No	Yes	2hop virtual routing pipe
4.	QF-AAVBF	2017	No	Hop-by-hop	Single Sink	No	Yes	Quadrature Vector pipe
5.	SD-VBF	2017	No	Hop-by-hop	Single Sink	No	Yes	Spherical Division Based vector pipe
6.	L2-ABF	2017	Yes	Hop-by-hop	Multi Sink	Multipath	No	Angle based flooding

Table 2: Parametric performance analysis of Depth-Based LQ Routing Protocols

S_No	Routing Protocol	Year	Node mobility Controlled	Hop-by-hop/end-to-end	Single/ Multiple Sink	Multipath	Hello/ Control Packet	Mechanism used
1	H2-DAB	2012	Yes	Hop-by-hop	Multi Sink	Multipath	Yes	Dynamic addressing
2	DCR	2013	Yes	Hop-by-Hop	Single Sink	No	No	Depth Controlled
3	MRP	2014	Yes	Hop-by-Hop	Multi-Sink	Multipath	Yes	Depth Information
4	D-DBR	2015	No	Hop-by-Hop	Single Sink	No	No	Directional angle with ToA
5	EMGGR	2017	No	Hop-by-Hop	Single Sink	No	No	Depth Information
6	3DGCS	2018	Yes	Hop-by-Hop	Single Sink	No	Yes	3D-Grid Clustering

Table 3: Parametric performance analysis of Energy-Saving LQ Routing Protocols

S_No	Routing Protocol	Year	Node mobility Controlled	Hop-by-hop/end-to-end	Single/ Multiple Sink	Multipath	Hello/ Control Packet	Mechanism used
1	LAFR	2013	Yes	End-to-End	Single Sink	No	No	Link state information with adaptive routing feedback
2	EE-DBR	2015	No	Hop-by-Hop	Single Sink	No	No	Directional angle with ToA
3	REEP	2015	No	End-to-End	Single Sink	No	Yes	Depth Information
4	EBDCR	2017	Yes	Hop-by-Hop	Multi-sink	Yes	No	Energy balanced and Depth Controlling
5	ACUN	2018	No	Hop-by-Hop	Single-Sink	No	No	Multi-level hierarchal architecture structure
6	EAVARP	2018	Yes	Hop-by-Hop	Single-Sink	No	Yes	Concentric shells through opportunistic directional forwarding strategy

4. Numerical simulation scenario performance analysis

Through this performance analysis, we have chosen the packets delivery ratio to compare the classification of link quality routing protocols, for simulation purpose we have chosen the NS2-3.0 simulator with AquaSim package. The different simulation parameters are used to see the performance of the protocols for packets delivery ratio (PDR). The parameters we have selected are mention in Table 4.

Table 4: Simulation Parameters.

Parameters	Values
Network Size	1500m x 1500m
No. of Nodes	300
Surface to bottom layer distance	250m
Data Packet size	64 byte
Initial Energy	70 J
MAC Protocol (27)	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
Transmission range	100 m to 150 m
Surface sink distance difference	100 m
Number of layers	7
Simulation time	1000 sec

PDR for Vector-Based Link Quality Routing Protocols

The PDR for Vector-Based Link Quality Routing protocols is shown in Fig. 2. In simulation results for packets delivery ratio which is measured in %, the PDR of QF-AAVBF is higher than other protocols as shown in Fig. 2, because the performance analysis of QF-AAVBF is based on optimal forwarder selection mechanism. It is also observed that the best selection route mechanism has also been selected by QF-AAVBF by consideration of underwater real parameters.

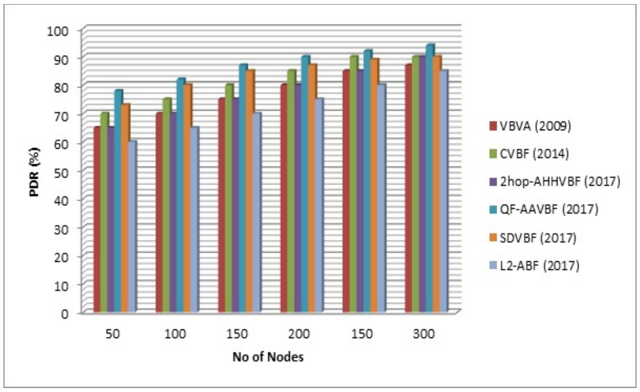

Fig. 2 PDR for Vector-Based Link Quality Routing Protocols

PDR for Depth-Based Link Quality Routing Protocols

The PDR for depth-based routing protocols is shown in Fig. 3. From the simulation response it is observed that the H2-DAB packets delivery ratio is higher than other depth-based protocols because H2-DAB is based on dynamic selection of addressing mechanism with respect to the depth. H2-DAB controls the depth through courier nodes.

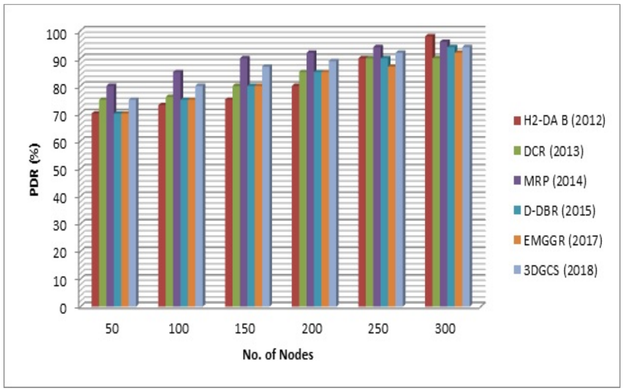

Fig. 3 PDR for Depth-based link quality routing protocols

PDR for Energy-Saving Link Quality Routing Protocols

The packets delivery ratio for energy-saving link quality routing protocols is shown in Fig. 4. The PDR for EBDCR is higher than other protocols because it controls the water depth and balance the energy consumption mechanism through winch-based module mechanism which has property to control the water depth and balance the energy level of the node.

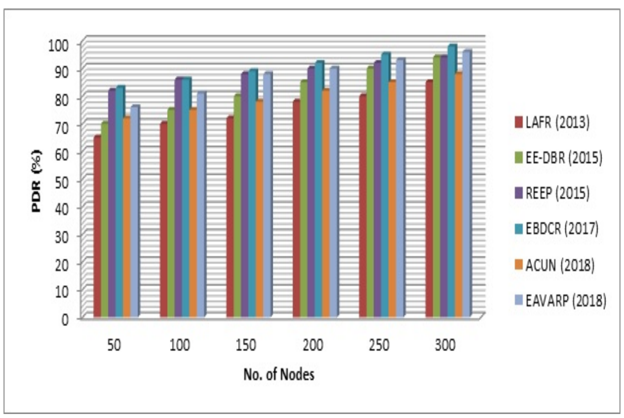

Fig. 4 PDR for Energy-Saving link quality routing protocols

5. Conclusion

This research article focuses the link quality routing protocols, to maintain the link quality in underwater environment, to maintain the link quality between nodes is one of the major issues which needs improvement. Majority of the researchers have resolved this major issue but still research needs improvement. In this research article the link quality routing protocols for underwater are classified into: vector-based routing protocols, depth-based routing protocols, and energy-saving link quality routing protocols. In each classification the algorithms/methods is defined to maintain the link quality between nodes is addressed through protocol operation. The demerits for each protocol have also been defined. This article also focuses the comparative analysis of the link quality protocols through parametric and simulation based comparison.

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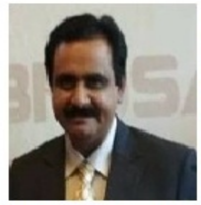

Dr. Mukhtiar Ahmed kori , did his PhD in Computer Science in 2017 from University Technology Malaysia (UTM), Dr. Kori currently working as an Assistant Professor in Department of Information Technology, Faculty of Science at Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah Sindh Pakistan. Dr. Kori completed his MS in Information Technology from Hamdard University Karachi Pakistan in 2009. Dr. Kori completed his MSc and BSc(Hons) from University of Sindh Jamshoro from 1989-1995. Dr. Kori has 25 years' experience in administration and teaching. He has more than 20 journal publications in area of UWSN, VANET, MANET, and WBAN. His mail id: mukhtiar.a@gmail.com

Sajida Parveen received her Bachelor of Engineering in Computer Systems from Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Pakistan in 2006. She completed her Master of Engineering in Communication Systems and Network from Mehran University of Engineering and Technology Jamshoro, Pakistan in 2011. Sajida earned her **PhD** from Universiti Putra Malaysia in 2016. She joined as a Lecturer in 2007 and currently working as Assistant Professor in the department of Computer Systems Engineering, Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Pakistan and her field of interest is communication, biometrics, security, image processing and machine learning.

Nazar Hussain Phulpoto is working as Associate Professor at the Department of Information Technology, QUEST Nawabshah. He has BS, MBA (QAU-Islamabad), MS (SZABIST- Karachi) andPhD (China) in Management Sciences. Dr. Phulpoto has more than 15 years of research and teaching experience. His research expertise includes mathematics, Management Sciences, Business Technology, Social networks, Management and Information Technology.

Nadeem Naeem received his B.E. in Electronic Engineering and his M.E. in Telecommunication and Control Engineering from Mehran University of Engineering and Technology, Jamshoro, Pakistan in 2006 and 2009. Currently, he earned **Ph.D** in Electronic Engineering from Universiti Putra Malaysia. His area of interest is electromagnetic devices and microwaves applications. He is working as Assistant Professor in Quaid-e-Awam University of Eng. Sci. & Tech., Pakistan.

Dr. Rajab Ali Malookani currently working as an Assistant Professor in Department of Mathematics and statistics, faculty of science, QUEST, Nawabshah, Pakistan. Dr. Malookani did his PhD in Applied Mathematics from Netherland, He did his MSc(Hons) from university of Sindh, Jamshoro Sindh Pakistan, He did his BSc from university of Sindh, Pakistan