Survey on Water-depth Controlling Routing Protocols for Underwater Wireless Sensor Networks

Mukhtiar Ahmed[1,2], Fauzia Talpur[1,3], M.Ali Soomro[2]
[1]*Department of Computer Science, Faculty of Computing, UTM, Malaysia,*
[2]*Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Sindh, Pakistan,*
[3]*University of Sindh, Jamshoro, Sindh, Pakistan.*

Abstract: Route controlling through underwater environment is one of the challenging tasks for researchers. Majority of the researchers have introduced the 3D deployment algorithms, localization-based algorithms, node mobility controlling algorithms, and water-depth controlling mechanisms. This research paper focuses the water-depth controlling protocols. The water-depth controlling mechanism is also still the major challenge because from sea surface to seabed there is long distance which affects the routing mechanism. This survey paper also focuses some issue with existing routing protocols which affects the water-depth. From the performance analysis it is observed that the directional depth controlling mechanism is well performer as compare to other defined water-depth controlling routing protocols.

Keywords: Clusters, vector-based, directional, flooding, seabed.

I. INTRODUCTION

Now days the underwater wireless sensor network is the main research area for researchers [1] due to its well know applications like: seismic monitoring, offshore explorations, pollution monitoring, oceanography data collection, disaster preventions, and assisted navigations [2]. In underwater environment the nodes are classified as: sink node which is almost deployed on water surface, the courier nodes, or Acoustic Underwater Vehicles (AUVs) which are the faster nodes and are responsible to collect the information from underwater nodes and transmit it to the sink nodes. Ordinary nodes are only the source for forwarding the data, and the source nodes are almost deployed at the seabed, which are responsible to collect the information from the seabed and forward it to the ordinary sensor nodes [3]. From sea surface to seabed the depth is uncontrollable due to the long distance, majority of the researchers have designed the routing protocols for controlling of the depth, but still research needs improvement [4-6]. The routing protocols, which controls the depth refers the top to bottom node mobility controlling mechanisms through horizontal and vertical modems [2, 7, 8].

II. RELATED WORK

Sector Based Routing Destination Location Prediction (SBR-DLP) is proposed by Chirdchoo, et al. [9]. SBR-DLP considers the long propagation, low data rate, high channel rate, and node mobility in its designing. Location based SBR-DLP is based on multi-sector routing algorithm [9]. In SBR-DLP the nodes are divided into multiple sectors. In Figure 1, the multiple sectors are shown and data packets can be forwarded from source to destination through the neighbor nodes with *Chk_Ngb* and *Chk_Ng_Rply* formats. In Table 1, the data forwarding mechanism between source and destination is mentioned with its distance calculation. Prior node mobility model defined by authors is simply the assumption; in real scenario this kind of model is flopped due to the water movement because node can move with respect to water pressure. The destination node may also be deviate from its position due to the water current and will reduce the packets delivery ratio.

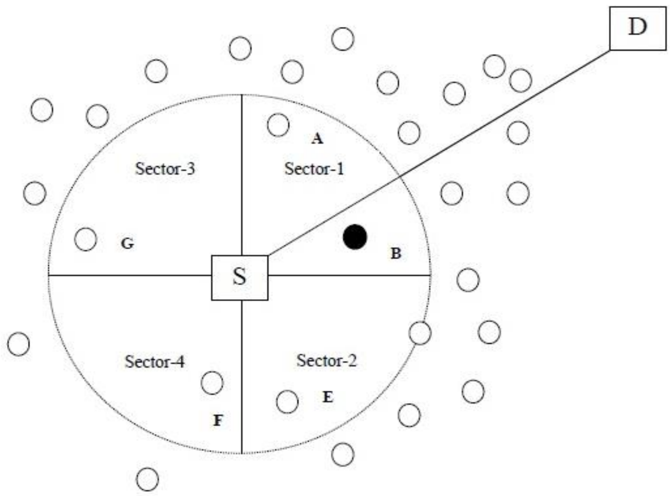

Figure 1: Forwarder selection at the sender in SBR-DLP

Table 1: How node *S* picks its next relay node

Sector	Candidates	Distance to D	After filtering
1	A,B	500,480	A,B
2	C	550	
3	-	-	
4	-	-	
		Next Relay Node	B

Hop-by-Hop Dynamic Addressing Based (H2-DAB) routing protocol proposed by Ayaz and Abdullah [10] uses the dynamic for controlling. It divides the water depth into different levels from surface to bottom. Some sensor nodes are placed at the bottom of the water and some are distributed in different depth levels from bottom to surface. In underwater the larger depth and smaller depth addressing mechanism has been adapted. The nodes which are nearer to sink have smaller addresses and when node goes to bottom level the addresses becomes larger. The addressing mechanism is developed by the sink node through *Hello packet.* The data forwarding mechanism between sensor nodes is based on greedy method algorithm. On arrival of data packets on surface sink nodes which show the successful receptions of data packets. All the surface sink nodes are connected between each other through radio signaling. Hop count mechanism and greedy algorithm of H2-DAB is not properly defined. The nodes nearer to the surface sink lose the energy more than the nodes deployed at bottom because they are used frequently.

Temporary Clustered Based Routing (TCBR) proposed by Ayaz, et al. [11]. TCBR is designed for balanced energy consumption mechanism with multi-hop. There are three kind of nodes are used in the designing of TCBR; sink nodes which are deployed on water surface, sensor nodes are placed in underwater in different water depths and are responsible to collect the data from the bottom of the water and forward that data to the relevant powerful courier nodes which are randomly deployed in underwater. Around the powerful courier nodes the temporary cluster formation mechanism is adapted. Powerful courier nodes are equipped with power full vertical embedded mechanical module which is responsible to push the data to the surface sink nodes. TCBR has utilized the communication range between 300 to 500 meters for better power usage. The formations of the clusters are just hypothesis and no clear concept of clustering mechanism is defined by authors. The powerful mechanical module concept is also just hypothesis; in real scenario this kind of node is not present. It is also observed that the approach used by TCBR is flopped in time critical scenarios.

Acoustic Underwater Routing Protocol (AURP) proposed by Yoon, et al. [12] is designed to resolve the issues like low available data rate due to acoustic channel, high bit error rate, and propagation delay due to distance. Sensor nodes are deployed in underwater and are responsible to collect the data and forward that data to the gateways in hop-by-hop manner, gateway nodes will forward the data to the nearest mobile acoustic underwater vehicles and acoustic underwater vehicles further forward the data to the sink nodes. Sink nodes are responsible to forward the data to the surface unit which is deployed on the water surface. Sometime underwater vehicles directly forward the important data to the Mothership which is also connected with surface unit. For path identification the phenomenon message (*PHE*) is used. *PHE* message covers the path length with number of underwater sensor nodes. In data forwarding mechanism the link can be developed through direct, multi-hop, or direct-multi-hop mechanisms.

Adaptive of Courier nodes in Threshold optimized Depth (AMCTD) proposed by Jafri, et al. [13] is based on four phases. First phase is initialization, in this phase the weight density of node is computed through entire network and movement of courier node is also observed according to the water pressure. Second is data forwarding phase, in this phase the optimal forwarder nodes with prioritization function calculates the weight for neighbour nodes which are nearer to source node. Third phase is consists of the updating weight and threshold for depth adaption; the entire network allocates the weight with depth prioritization and residual energy is changed according to sparse network. The fourth phase covers the courier node movement with variation in threshold of depth according to sparse network. It is observed that the weight calculation mechanism of AMCTD is not so easy in sparse network because depth calculation mechanism for sparse network is complicated.

Cluster Vector Based Forwarding (CVBF) proposed by Ibrahim, et al. [14] considers the sparse and dense area of underwater to enhance the data delivery ratio and to reduce the end-to-end delay. Authors claimed that CVBF is better than VBF, HH-VBF, VBVA, and ES-VBF. CVBF approach divides the whole network into the nine numbers of predefined clusters. The four types of the sensor nodes are used for data forwarding mechanism, one is the sink node deployed on water surface, second is source node which is at the bottom of the water, third is cluster sink node, and fourth is cluster member node as shown in Figure 2. Every cluster has one virtual sink node and member nodes. In every cluster the member nodes are responsible to forward the data packets to their respective virtual sink. In every cluster the data forwarding mechanism is adapted from VBF. The algorithm defined by CVBF is based on three steps: (i) clustering the nodes (ii) selecting the cluster virtual sink and (iii) clustering maintenance time. Virtual sinks are responsible to collect the data from the cluster member nodes and forward the data packets to the main sink node. In CVBF the void nodes will degrade the performance of CVBF. Virtual pipe and number of clusters deployment mechanism is not suitable for underwater environment because due to continuous water pressure the formation of clusters and virtual pipe may be affected.

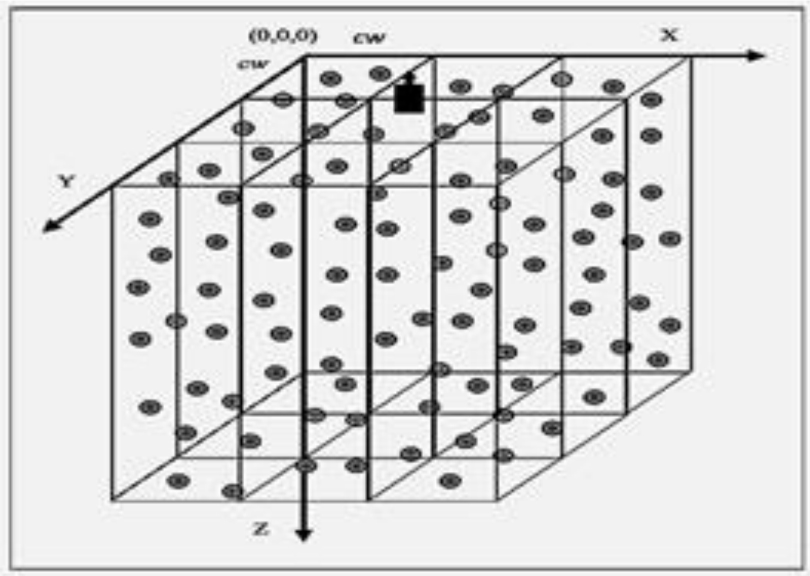

Figure 2: CVBF network of clusters [14]

Dynamic Sink Mobility (DSM) Depth Based proposed by Khan *et al*. (2015) maximizes the stability, throughput, and lifetime of network. In DSM the nodes are deployed randomly, the 3D underwater environment is divided into four rectangular regions with four groups of nodes. In DSM the node density can be calculated for separate region and sink moves towards the regions which keep the maximum node density. Sink node receives data from the center of region through nodes and AUVs. AUV is also responsible to move towards rest of the regions and collects the maximum data and broadcast to the movable sink node. In DSM the limited area of the 3D environment of water is divided into four regions. It is observed that the environment of 3D water with division of four regions is not the stable approach due to water pressure and node mobility.

Directional Depth Based Routing (D-DBR) proposed by Diao, et al. [16] is based on optimal route selection through ToA ranging technique from source to sink. It uses the minimum number of hop from source to sink for data forwarding. Sink node with high battery power is deployed on the surface of water and sensor nodes are deployed at depth of water. The angle holding time function is used for route directives. Like EEDBR the D-DBR also cannot achieve the high delivery data ratio in sparse area. No proper methodology is defined by D-DBR for the energy saving of ordinary sensor nodes. Void regions are the main problem in underwater environment; so an efficient mechanism for removal of voids is not properly defined. If forwarder node becomes as a void node and it drop the packets continuously will die earlier which will reduce overall network throughput.

III. PERFORMANCE ANALYSIS

The performance analysis for water depth-based routing protocols is shown in Table 2. The parameters which are defined for performance analysis are geographic location, hop-by-hop/end-to-end delay, technique for packets forwarding is either single or multipath, which techniques the water-depth controlling routing protocols follows and protocols either refers the hello or control packets for activation or not. From performance analysis it is observed that the routing protocols which are based on multiple sink nodes with multipath packets forwarding are the well performer in the environment of the underwater.

Table 2. Performance analysis through metrics for water-depth controlling Routing Protocols

S_No	Routing Protocol	Year	Geographic Location		Hop-by-hop/end-to-end	Single/ Multiple Sink	Multipath	Technique used	Hello/Control Packet
			Location	Depth					
1.	SBR-DLP	2009	√	×	hop-by-hop	Single-sink	×	Multicasting	yes
2.	H2-DAB	2009	×	√	hop-by-hop	Multi-sink	√	Dynamic addressing	yes
3.	TCBR	2010	×	√	hop-by-hop	Multi-sink		Temporary cluster formation	yes
4.	AURP	2012	×	√	hop-by-hop	Single-sink	√	Periodically flooding with PHE	yes
5.	AMCTD	2013	×	√	end-to-end	Multi-sink	√	Adaptive mobility Depth-based	yes
6.	CVBF	2014	√	×	end-to-end	Single-sink	×	Cluster of virtual routing pipes	no
7.	DSM	2015	√	×	hop-by-hop	Single-sink	×	Broadcasting	no
8.	D-DBR	2015	×	√	hop-by-hop	Single-sink	√	Broadcasting	no

IV. CONCLUSION

Water-depth controlling routing protocols controls the depth of water from top to bottom; the researchers have controlled the water depth through horizontal and vertical packets forwarding controlling approaches. From aforementioned routing protocols the H2-DAB control the water depth through depth addressing mechanism but the uncontrollable node mobility affects its overall throughput. The CVBF routing protocol controls the water depth through formation of clusters within multiple routing pipes, it is observed that the limited diameter of routing pipe drops the data packets. The D-DBR utilizes the diagonal distance approach for packets forwarding, it is observed that some constant the D-DBR performance is reasonable as compare to other water-depth controlling protocols.

REFERENCES

[1] M. Ahmed, M. Salleh, and M. I. Channa, "Critical Analysis of Data Forwarding Routing Protocols Based on Single path for UWSN," *International Journal of Electrical and Computer Engineering*, vol. 6, pp. 1695-1701, 2016.

[2] F. Al Salti, N. Alzeidi, and B. R. Arafeh, "EMGGR: an energy-efficient multipath grid-based geographic routing protocol for underwater wireless sensor networks," *Wireless Networks*, vol. 23, pp. 1301-1314, 2017.

[3] I. F. Akyildiz, D. Pompili, and T. Melodia, "Underwater acoustic sensor networks: research challenges," *Ad hoc networks*, vol. 3, pp. 257-279, 2005.

[4] B. Ali, A. Sher, N. Javaid, K. Aurangzeb, and S. I. Haider, "Retransmission Avoidance for Reliable Data Delivery in Underwater WSNs," *Sensors*, vol. 18, p. 149, 2018.

[5] N. Goyal, M. Dave, and A. K. Verma, "A novel fault detection and recovery technique for cluster-based underwater wireless sensor networks," *International Journal of Communication Systems*, vol. 31, p. e3485, 2018.

[6] J. Wen, D. Li, L. Liu, and J. Yuan, "An estimated Hungarian method for data forwarding problem in underwater wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 14, p. 1550147718772538, 2018.

[7] S. Gul, S. H. Jokhio, and I. A. Jokhio, "Light-weight depth-based routing for underwater wireless sensor network," in *Advancements in Computational Sciences (ICACS), 2018 International Conference on*, 2018, pp. 1-7.

[8] R. Gomathi and J. M. L. Manickam, "Energy Efficient Shortest Path Routing Protocol for Underwater Acoustic Wireless Sensor Network," *Wireless Personal Communications,* vol. 98, pp. 843-856, 2018.

[9] N. Chirdchoo, W. S. Soh, and K. C. Chua, "Sector-based Routing with Destination Location Prediction for Underwater Mobile Networks," *2009 International Conference on Advanced Information Networking and Applications Workshops: Waina, Vols 1 and 2,* pp. 1148-1153, 2009.

[10] M. Ayaz and A. Abdullah, "Hop-by-Hop Dynamic Addressing Based (H(2)-DAB) Routing Protocol for Underwater Wireless Sensor Networks," *2009 International Conference on Information and Multimedia Technology, Proceedings ICIMT'09. IEEE.,* vol. jeju Island, Korea, pp. 436-441, December 2009.

[11] M. Ayaz, A. Abdullah, and L. T. Jung, "Temporary cluster based routing for underwater wireless sensor networks," in *Information Technology (ITSim), 2010 International Symposium. IEEE.*, Malaysia, June 2010, pp. 1009-1014.

[12] S. Yoon, A. K. Azad, H. Oh, and S. Kim, "AURP: An AUV-aided underwater routing protocol for underwater acoustic sensor networks," *Sensors,* vol. 12, pp. 1827-1845, 2012.

[13] M. R. Jafri, S. Ahmed, N. Javaid, Z. Ahmad, and R. J. Qureshi, "AMCTD: Adaptive Mobility of Courier nodes in Threshold-optimized DBR Protocol for Underwater Wireless Sensor Networks," *2013 Eighth International Conference on Broadband, Wireless Computing, Communication and Applications (Bwcca 2013), IOS press,* vol. COMPIEGNE, FRANCE,, pp. 93-99, 2013.

[14] D. M. Ibrahim, M. M. Fahmy, T. E. ElTobely, and E. A. Sallam, "Enhancing the Vector-Based Forwarding Routing Protocol for Underwater Wireless Sensor Networks: A Clustering Approach," in *The Tenth International Conference on Wireless and Mobile Communications (ICWMC). IARIA.*, Seville, Spain, 2014, pp. 98-104.

[15] A. H. Khan, M. R. Jafri, N. Javaid, Z. A. Khan, U. Qasim, and M. Imran, "DSM: Dynamic Sink Mobility Equipped DBR for Underwater WSNs," *Procedia Computer Science,* vol. 52, pp. 560-567, 2015.

[16] B. Diao, Y. Xu, Z. An, F. Wang, and C. Li, "Improving Both Energy and Time Efficiency of Depth-Based Routing for Underwater Sensor Networks," *International Journal of Distributed Sensor Networks,* vol. 11, pp. 1-9, 2015.