Comparative analysis on Link-aware Routing Protocols for Underwater Wireless Sensor Network

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: Underwater Wireless Sensor Network becomes more attractive area for researchers due to its well-known applications like: oil/gas, silver, gold, minerals, ocean monitoring, pollution monitoring, tactical surveillance etc. The researchers are mining the application based information from underwater through designing of routing protocols. The designing of the link-aware routing protocols is one of the challenging tasks due to underwater obstacles like: acoustic channel limitations, propagation delay, water pressure, water current which effects the node movement and node may drop the packets. This research article focuses the link-aware routing protocols with their limitations and drawbacks. The performance analysis through analytical method focuses the unique parameters through which we can examine which protocol is controls the link quality in underwater environment.

Keywords: link-quality, link-aware, propagation-delay, packets-delay, water-pressure.

I. INTRODUCTION

Underwater wireless sensor network is nowadays a very famous field for wireless sensor network researchers due to the majority number of applications. The researchers are extracting the information from the seabed for oil and gas, minerals, gold, silver and many more through routing protocols [1-3]. The designing of routing protocols is not an easy task in underwater wireless sensor network due to acoustic channel limitations, propagation delay, low battery power, water pressure and water current [4-6]. The underwater obstacles, water pressure and water current affects the link quality of the for routing path [7, 8] due the node mobility. This research paper focuses the link-aware routing protocols with its advantages, limitations and metric performance analysis.

II. RELATED WORK

i. Vector Based Forwarding

Vector Based Forwarding (VBF) proposed by Xie, Cui [9] is geographic routing protocol which does not require any stateless information of the sensor nodes. The position of source, destination, and forwarder nodes are included in the header of the data packets which is transmitted using VBF [10]. The virtual pipe (vector) can be created between the two nodes by using the position of source and destination; through the virtual pipe the packets can be forwarded. Consider the example shown in Figure 1 where S1 and D1 are source and sink nodes, respectively. A vector of $(S1D1)^{\rightarrow}$ is established between source and destination through virtual pipe. In VBF only the limited nodes within the virtual pipe are involved to forward the packets to the destination. Therefore VBF needs only the position of destination node. In VBF if any node receives the packets and is closer to the routing vector line between S1 and D1 then that node includes their position into the packet header as the forwarder and transmits the packets. In Figure 1 the t, p and k nodes received the packets and are neighbors of source node, these nodes are considered as the potential forwarder nodes. Node k; which is not placed in the virtual pipe, discards the received packets. To define the pipe, a predefined distance threshold w for the closeness of nodes to the line between source and destination is considered [10]. VBF refers the self-adaption algorithm to reduce the number of forwarding nodes and conserve energy. The node may be the potential forwarder or may be the potential candidate, potential candidate node waits for the period of time determined by its desirable factor. Desirable factor shows the nearness of the node to the previous forwarder, and the vector between S1 and D1. The more desirable the node, the less time it must wait. During the wait time the node has ability to listens to the medium to see how many nodes are forwarding the same packets as the current node. When a candidate's wait time expires, it forwards its packet if the minimum desirability factor of the other forwarders is less than a predefined value. In node forwarding mechanism the few nodes are involved for data forwarding which focuses the robustness and scalability. VBF has some serious problems: a network with low density or node movement, it is possible that the number of nodes located in the virtual pipe from source to destination is few or none, which will degrade the overall performance of the network. Furthermore if in virtual pipe the forwarder nodes continuously forward the packets then they may lose their energy level and dies earlier. The void node removal and link quality is affected due to limited radius of routing pipe.

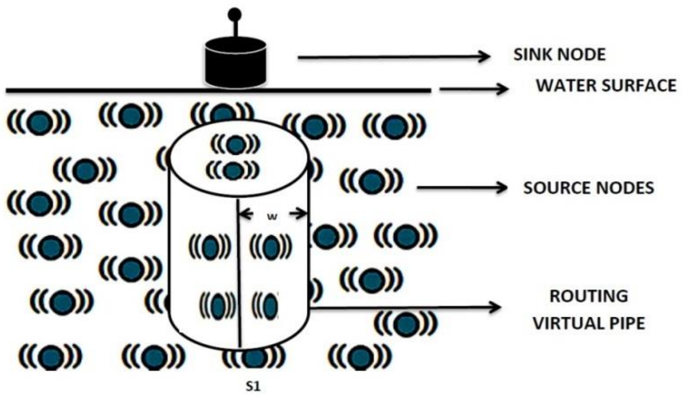

Figure 1: An illustration of VBF [9]

ii.Location-Ware Source Routing Protocol

Location-Aware Source Routing (LASR) proposed by Carlson, Beaujean [11] is the modified version of the Dynamic Source Routing (DSR), but suffers from high latency in the underwater acoustic environment. LASR uses two techniques to resolve the high latency problem; the first is link quality and the second is location awareness. DSR protocol is designed for shortest path and LASR is designed for the selection of better routes throughout the network by using the Expected Transmission Count (ETX). ETX is better for the link quality and ETX can be calculated as given in Equation (1).

$$ETX \triangleq 1/((1-FER)^2) \quad (1)$$

In Equation (1) FER denotes the Frame Error Rate. For route development mechanism is based on route selection, acknowledgment, and route reply. For updating of route link the Dijkstra's algorithm is used. The option packing, acknowledgement-delay-guarantee, and hello message based options are used for packets forwarding. The tracking system has used the state-estimation and recursive mechanism to calculate the range with network topology. LASR has adapted the mechanism of DSR and if the hop counts between source and destination increases the size of the packets' header also increases and in resultant the overheads increases with narrow band for communication in underwater. Through ETX the links are considered as a symmetrical with same link quality; in underwater environment the symmetrical link quality maintenance is not possible because within few minutes the link may be broken due to water pressure and environmental conditions of water [12].

iii. Hop-by-Hop Vector Based Forwarding Routing Protocol

Hop-by-Hop Vector Based Forwarding (HH-VBF) proposed by Nicolaou, See [13] is the extension of VBF [14] which eliminates the drawbacks of VBF. From source to sink node the multiple number of pipes are used to enhance the data rate. The forwarder node is responsible to compute the vector itself with every number of hop from source to sink node [15] . The better approach for enhancement of data delivery is used but HH-VBF still faces some issues like: the re-computation on each hop affects the performance in sparse area. Continuous use of the hop-by-hop approach increases the signaling overheads and will affect the overall network throughput. Node mobility model is not properly be defined which affects the links between nodes.

iv. Information-Carrying Routing Protocol

Information-Carrying Routing Protocol (ICRP) proposed by Liang, Yu [16] is localization free, scalable and energy efficient routing protocol based on single path. Its route development mechanism is based on source node through route discovery message. On arrival of route discovery message the neighbor nodes are responsible to develop the reverse route through acknowledgement. When route established the source node will forward the packets and will wait for acknowledgment through reverse route. The established routes refer the TIMEOUT function, if the threshold time exceeds the TIMEOUT then route become invalid. When the data packets received through the established route to the destination the delivery refers the successful packets delivery. In ICRP node mobility model is invalid due to water pressure. Route information and TIMEOUT function mechanisms may drop the packets due to void regions. In ICRP if the route remain valid for short or long time period will affect the data delivery ratio because route duration in underwater may remain up to 2 to 3 seconds.

v. Distributed Underwater Clustering Scheme

Distributed Underwater Clustering Scheme (DUCS) proposed by Domingo and Prior [17]. DUCS is scalable routing protocol. DUCS routing protocol is designed for long-term applications [12]. DUCS utilizes the distributed routing algorithm for development of multiple clusters. In every cluster the formation of cluster-head and non-cluster head nodes are developed by DUCS. Non-cluster heads are responsible to forward the data packets to their relevant cluster-head nodes through single-hop mechanism. From cluster-head nodes to other cluster-head nodes the data may be forwarded through multi-hop mechanism with the use of aggregation function. The cluster-head nodes which are nearer to sink node will forward the data to the sink nodes which are deployed on the water surface. Setup and operation phases focus the performance of the DUCS; the cluster formation mechanism refers the setup phase whereas in operation phase data may be forwarded. Intra-cluster coordination mechanism refers the communication between non-cluster and cluster-head nodes and inter-cluster coordination refers the communication between cluster-head and other cluster-head nodes. The communication between non-cluster head and cluster-head nodes is based on forwarding of frames and frames are the composition of data messages. It is observed that during cluster formation mechanism the movement of the node affects the performance of the entire network. The movement of the cluster-head nodes also reduces the packets delivery ratio.

vi. Depth Based Routing protocol

Depth Based Routing (DBR) is proposed by Yan, Shi [18]. In data forwarding mechanism the each sensor node makes its own decision on its depth with the depth of the previous sender node. Figures 2 focuses the data forwarding mechanism with the sender node S and the neighbor nodes n1, n2 and n3; but the candidate forwarder nodes n1 and n2 are nearer to the sink node deployed on the water surface. In count the n1 is nearer to sink node and is preferred to forward the packets and n2 will remain on wait state. DBR handles the resources in efficient way without requiring the full dimensional location information of sensor nodes. The main drawback of DBR is that if the multiple copies of same packets are distributed by sensor nodes then in resultant the packets collision will occur with delay in transmission, and as well as high energy will be consumed.

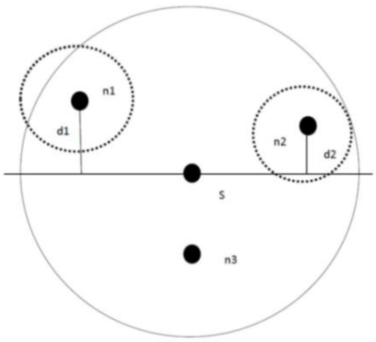

Figure 2: Forwarding node selection in DBR [18]

vii. Directional Flooding Routing protocol

Directional Flooding Routing (DFR) proposed by Hwang and Kim [19] refers the mechanism of HH-VBF and VBF. The control flooding of DFR enhances the data delivery ratio. Its link quality and data forwarding mechanism involves the maximum number of nodes to enhance the network throughput. The problem of void region has been resolved through one node participation mechanism but the removal of void node is not properly be defined when the node comes in the void region. Even in DFR the multiple copies of same data packets are forwarded to the sink node which utilizes the maximum resources and the extra burden increases which reduces the performance of the entire network.

viii. Underwater Wireless Hybrid Sensor Networks protocol

Underwater Wireless Hybrid Sensor Networks (UW-HSN) proposed byAli and Hassanein [20].

UW-HSN considers the issues like signal attenuation, propagation delays, low bandwidth, and energy consumption for shallow water. For large and continuous communications the authors have used the radio and acoustic signaling system. In underwater the sensor node uses the acoustic signaling whereas on surface level the sensor node uses the radio signaling to communicate with base station. In UW-HSN the sensor nodes have ability to move on surface level and can dive back to different levels of water with the help of the installed mechanical module. The authors have used the TurtleNet hybrid concept for negative and positive vertical movements of the node through piston to reach on surface and dive back to the bottom depth levels of water. Through Trutle Distance Vector (TDV) algorithm the communication channel minimizes the average event delay; event delay means successful reception time duration between source nodes and base station. In UW-HSN energy consumption model and parameters are not properly defined. The hardware used by UW-HSN increases the overall cost of the network.

III. PERFORMANCE ANALYSIS

In Table 1, the performance analysis through parametric mechanism for link-aware routing protocols is shown, comparison parameters are: geographic location (location or depth), hop-by-hop or end-to-end delay, single sink or multiple sink nodes, multipath, technique used, and hello or control packets. The performance analysis is based on the algorithm operation for packets forwarding.

Table 1. Link-aware Routing protocols parametric comparison

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.	VBF	2006	√	×	end-to-end	Single-sink	×	Virtual routing pipe	no
2.	LASR	2006	√	×	end-to-end	Single-sink	×	Location aware	yes
3.	HH-VBF	2007	√	×	hop-by-hop	Single-sink	×	Virtual routing pipe	no
4.	ICRP	2007	√	×	end-to-end	Single-sink	×	Broadcasting	no
5.	DUCS	2007	×	√	hop-by-hop	Single-sink	×	Random node mobility	yes
6.	DBR	2008	×	√	hop-by-hop	Multi-sink	√	Broadcasting	no
7.	DFR	2008	√	×	hop-by-hop	Single-sink	×	Packet Flooding	no
8.	UWHSN	2008	×	×	hop-by-hop	Single-sink	×	TurtleNet Distance vector	yes

IV. CONCLUSION

The link-aware routing protocols are based to control the link quality for packets forwarding, it is observed that link quality of the aforementioned routing protocols are affected due to the water pressure because water pressure affects the node mobility and majority of the nodes are dropping the data packets and it is observed that due to packets dropping the end-to-end delay remained increased. From the aforementioned routing protocols it is observed that the hop-by-hop based routing protocols in some constant controls the link quality but due to the increased number of hops the network throughput remained low.

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