International Journal of Electrical and Computer Engineering (IJECE)
Vol. 7, No. 1, February 2017, pp. 536~541
ISSN: 2088-8708, DOI: 10.11591/ijece.v7i1.pp536-541

Review on Localization based Routing Protocols for Underwater Wireless Sensor Network

Mukhtiar Ahmed[1], Mazleena Salleh[2], M. Ibrahim Channa[3], Mohd Foad Rohani[4]
[1,2,4]Department of Computer Science, Faculty of Computing, Universiti Teknologi Malaysia (UTM), Malaysia
[1,3]Department of Information Technology, Quaid-e-Awam University of Engineering, Science and Technology (QUEST), Nawabshah, Sindh, Pakistan

Article Info

Article history:

Received Oct 15, 2016
Revised Dec 15, 2016
Accepted Dec 30, 2016

Keyword:

Data forwarding
Location based
Network performance
Packets delivery
Route link

ABSTRACT

Underwater Wireless Sensor Network (UWSN) can enable many scientific, military, safety, commercial and environmental applications. Majority of the network models has been introduced for the deployment of sensor nodes through routing schemes and methodologies along with different algorithms but still the design of routing protocol for underwater environment is a challenging issue due to distinctive characteristics of underwater medium. The majority of the issues are also needed to fulfill the appropriate approach for the underwater medium like limited bandwidth, high bit error rates, propagation delay, and 3D deployment. This paper focuses the comparative analysis of the localization based routing protocols for UWSN. This comparative analysis plays a significant attention to construct a reliable routing protocol, which provides the effectual discovery of the route between the source node and the sink node. In addition this comparative analysis also focuses the data packets forwarding mechanism, the deployment of sensor nodes and location based routing for UWSN in different conditions.

Corresponding Author:

Mukhtiar Ahmed,
Department of Computer Science,
Faculty of Computing,
Universiti Teknologi Malaysia,
Skudai Johar Bahru, Malaysia.
Email: Mukhtiar.a@gmail.com

1. INTRODUCTION

Underwater Wireless Sensor Networks is a main focus of the majority of the researchers who research in the field of the Computer Networking specially Wireless Sensor Networks. The earth planet covers 75% by sea and ocean [1]. UWSN provides promising solutions for discovering aqueous environment efficiently for military, emergency and commercial purposes [2]. Unmanned or Autonomous Underwater Vehicles (UUVs, AUVs), equipped with underwater sensors, are also envisioned to find application in exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions [3]. Underwater acoustic communication has been introduced from last fifty years; the first underwater device by name phone has been made by US Navy after World War II [4].

There are three kinds of waves, optical, electromagnetic and acoustic can be used for underwater communication wireless sensor networks [5], [6]. Electromagnetic waves are affected by attenuation in water because of high frequencies thus require high transmission power and large antenna [7] . Optical waves has ultra-high data rate communication in terms of Gbit/sec but drawback is that; these waves rapidly scattered and absorbed in water; so these are only suitable for the shortest distance link [8], [3] .

The acoustic signals are well preferable for underwater communication because of long range links and they suffer from relatively low absorption. The acoustic type of waves is the longitudinal waves that

propagate by means of adiabatic compression and decompression. These waves vibrate in the same direction with respect to its travel direction. Acoustic signals can travels with the speed of sound accordingly to the medium. The acoustic signals characteristics are measured with the sound pressure, velocity of particles, intensity of sound and displacement of particles. The employment of acoustic signals imposes many distinctive challenges on UWSN i.e. large propagation delay (1500 m/sec), limited bandwidth, (<100 KHz) and high bit rate due to extreme characteristic of the underwater channel [9]. In underwater environment the local sensor nodes cannot work properly due to its limited energy [10]. To replace the batteries of the local sensors are highly expensive. It is important to prolong the life time of such sensor nodes through the deployment mechanism in UWSN.

Due to the majority of the challenges for underwater environment, the researchers have designed the number of routing protocols like MAC Protocols, Network Protocols and Transport Protocols. The Routing protocols for underwater environment can be classified mainly in two categories, one is the localization based category and other is the localization free category. The main focus of this comparative analysis is on localization based protocols.

The localization based Protocols emphases the locations of the sensor nodes in underwater environment. The first approach for localization based protocols has been given in the designing of Vector Based Forwarding protocol (VBF) [11]. In VBF the source node computes a vector from itself towards the destination. No state information is required on the sensor nodes and only a small portion of the nodes involved in the routingmechansim. Moreover, in VBF, the forwarding of packets from source to destination; only the redundant and enclosed path is required. Furthermore, the authors have adapted the distributed self-adaption algorithm with localization to increase the performance evolution of VBF. Through the self-adaptation algorithm the authors have reduced the energy consumption. The authors evaluated the performance of VBF through simulations by using NS-2 simulator. The outcomes of the VBF show the medium or small node mobility, VBF target goals are: i. high success rate of data delivery, ii. energy efficiency, and iii..robustness. Authors have focused the three parameters, success rate of packets, energy consumptions by nodes and average delay of packets. In VBF source node computes the vector. In the computed range of vector along with pipe radius; the residual nodes can be involved in forwarding mechanism. The vector area is called the routing pipe. The VBF scheme outside the routing pipe controls data packets through flooding mechanism. In this scheme the major drawback is that; in case of sparse density the unobtainability of nodes in routing pipe will affect the forwarding mechanism, another drawback is that; the localization assumption factor will also affect its performance.

2. BACK GROUND

The main focus of this survey paper is to describe the location based protocols in depth and evaluate its advantages and disadvantages for underwater environment. The following localization based routing protocols are involved for the comparative analysis.

a) Vector-Based Forwarding (VBF) Routing Protocol
b) Hop by Hop Vector Based (HH-VBF) Routing Protocol
c) Focused Beam Routing (FBR) Routing Protocol
d) Directional Flooding based Routing (DFR) Routing Protocol
e) Sector Based Routing Destination Location Prediction (SBR-DLP) RP
f) Location-aware Source Routing (LASR) Protocol
g) A Reliable and Energy Balanced Routing Algorithm (REBAR)

2.1. Vector-Based Forwarding

In [12] the Vector Based Forwarding (VBF) is proposed. VBF is based on node mobility and energy efficiency. In this protocol; each packet is consists of five fields: *SP (Sender Position), TP (Target Position), FP (Forwarder Position), RANGE (Mobility of node)* field, and *RADIUS (Radius of pipe). RANGE* field also controls the *TP*. In addition the authors have also introduced the *routing pipe* and *radius pipe*. The *routing pipe* controls *SP* and *TP*, whereas *radius pipe* controls *RADIUS*.

VBF Routing focuses the two queries: one is *SI_QUERY* (Sink_Initiated QUERY) and other is *S$_r$I_QUERY* (Source_Initiated QUERY).

The *SI_QUERY* further divided into: one is *location dependent query* and other is *location independent query*. *Location independent query* allocates the area for destination node. The area of destination is called the location. The *location dependent query* stares for data. Furthermore in *location dependent query*; the destination node will release the *INTEREST* query. The *INTREST* query will set the coordinates of the source and destination nodes by using the *SINK-BASED-COORDINATE* system. *INTREST* query also keeps the information of the source and destination nodes. The *location independent query* floods

the destination node, so it will generate the *INVALID* message for the position of destination node. *Location independent query* also computes the location of envisioned nodes through *SINK-BASED-COORDINATE* system and forward the data packets to the destination nodes.

Source_Initiated Query sets the source node with *DATA_READY* message for transmits. In *Source_Initiated query* every node computes the location through *SOURCE-BASED-COORDINATE* system. The destination node will shift the position of the source node to its own coordinate system, after that it will transform location-dependent *INTEREST* packet to the source node for to compute the position with respect to *SINK-BASED-COORDINATE* system for the succeeding communication.

2.2. Hop by Hop Vector Based (HH-VBF)

In [13] HH-VBF is proposed. Authors of this paper have focused the two major drawbacks of VBF Routing Protocol for underwater environment.

(1) Data delivery ratio despoiled due to the single virtual pipe. Vector based forwarding scheme has used the unique source node to destination node vector based approach; the node density area may be affected by using of the single virtual pipe. VBF has also used the sparse distributed mechanism which affects the node forwarding mechanism.
(2) The routing performance will be affected with the threshold level of routing pipe in real scenarios.

HH-VBF is the advance version of VBF, because the authors of the HH-VBF eliminate the drawbacks of VBF with its solution; the author has used the multiple virtual pipes around the hops for source and destination nodes. HH-VBF focused the two benefits: (a) from the multiple virtual pipes the every node lies on its own pipe with respect to its transmission range. Pipe radius may increase the routing performance. (b) In simulation results the author has shown the increased data delivery ratio in comparison of VBF; because authors have used the sparse type of network with new design patterns.

The authors of this paper have created the multiple virtual pipes according to hop by hop approach. Hop-by-Hop approach increases the probability in finding the path for forwarding of sensor nodes. Furthermore just consider the node N_i, which receives a packet from the source or a forwarder node S_j, upon receipt of the packet, the node computes the vector from the forwarder node S_j to the destination node or sink node. In HH-VBF on its hop by hop levels the forwarder pipe gets changes. Candidate forwarder node will compute the distance vector if distance appears as a small than packets will be forwarded.

2.3. Focused Beam Routing (FBR) Routing Protocol for UWSN

In [14] FBR is proposed. FBR is a scalable routing technique for multi-hop ad-hoc networks based on location information. In this technique the nodes must know their own position and the position of the final destination of the packet. This technique is suitable for networks containing both static and mobile nodes. FBR is a cross-layer architecture, in which the MAC, the routing protocol, and the physical layer functionalities are tightly coupled by power control. In this technique the authors have focused on distributed algorithm, in which a route is dynamically established as the data packet traverses the network towards its final destination.

In FBR the energy consumption is reduced due to confine flooding of transmission. The assumption has been adapted with the matching of transmission radius R_n through finite number of energy level from P_1 to P_N (open loop power control levels). From source node to the destination nodes the forwarder candidate determines with its cone angle. On the P_1 (power level 1) the node with ***RTS*** status send the message and on the same power level the sink node will reply with ***CTS*** packets. Assume that if source node not receives the reply on power level 1, then the power level will be increased from level 1 to level 2 with new ***RTS*** message, the repetition of this process continued till the arrival of ***CTS*** packets from source to sink node. Assume that if the maximum power level has been utilized and no connection developed between sources to sink nodes, than the source node will change the power level towards left/right side of the new cone. The performance evolution of FBR has been evaluated with discrete event simulator. The authors of FBR have claimed the discovery of minimum energy level through their simulation results. In FBR the authors have compare the impact of the node density with the famous algorithm called the Dijkastra's algorithm.

2.4. Directional Flooding based Routing (DFR) Routing Protocol for UWSN

In [15] DFR is proposed. DFR is composite of two major techniques one is VBF and other is HH-VBF. The authors of this routing protocol has focused the control flooding scheme in order to achieve the reliable packets delivery. DFR protocol is unique due to the two approaches one is maximum number of nodes involved in forwarding mechanism and second is link quality between nodes. The authors have used the "*Packets Forwarding Decision*" algorithm, which basically focuses the methodology for the packets forwarding.

2.5. Sector Based Routing Destination Location Prediction (SBR-DLP) Routing Proto

In [16] SBR-DLP is proposed. The authors of this research paper have proposed the Multi-Sector based routing algorithm. SBR-DLP focuses the node mobility for underwater sensor networks where the destination nodes can also move along with other nodes in the network. The authors claimed that SBR-DLP can overcome on: *Long propagation delay, Node mobility, High channel error rate,* and*Low data rate.*

The SBR-DLP is a location based routing protocol. In this protocol the sensor nodes does not carries any information about its neighboring nodes nor the network topology [17]. Through multi-sector based routing algorithm the authors have divided the sensor nodes into multiple sectors *(1,2,3,……,n-1);* and sensor nodes are labeled with: ***A,B,C,……..,N-1***. The information can be transferred from source to destination by ***Chk_Ngb*** format. The ***Chk_Ngb*** (Check Neighbor) format is consists of two fields' ***current position*** and ***Packets_ID***. Source node will transfer the ***Chk_Ngb***format to the destination node, after some time interval the destination node will acknowledge with ***Chk_Ng_Rply*** (Check Neighbor Reply) message along with hop condition to the source node.

2.6. Location-Aware Source Routing protocol for UWSN

In [17] LASR is proposed. LASR is the location based protocol and the revised form of the DSR (Dynamic Source Routing) protocol. The LASR protocol has used the two extra methods; one is the location awareness and second is the link quality metric. In location awareness method; the authors have designed the local network topology which uses the implicit information for transmission. The local network topology consists on tracking system and time-of-flight for range and transmission process. The authors have also used the TDMA technique for medium access control. The link quality metric uses the DSR for hop count and powerful computational methods are adapted for the improvement of link quality. LASR has used the robust link quality for hop count, the link quality is consists of two end points, link quality metric and time stamp. The link quality has also used the Expected Transmission Count (ETX) [20]. The ETX can be calculated as given in Equation (1).

$$\mathrm{ETX} \triangleq \frac{1}{(1-\mathrm{FER})^2}. \qquad (1)$$

In Equation (1) FER denotes the Frame Error Rate. LASR link quality protocol header is consists on octal 12-bit. The time stamp factor is used for new data link. LASR also guarantees for state less link type data; it can correctly be discarded through some mechanism.In LASR every route is re-calculated on every hop count, the route principally serves to spread the network topology. The link cache mechanism is updated with the new data and the route. The route can be replaced when the implicit information appears to build the link cache. LASR has used the Dijkstra's algorithm for updating the network graph [21]. Route handling mechanism will use the protocol options to develop the route link, these options are *acknowledgement, route selection* and *route reply*. The link could be cast-off before the departure of option.

2.7. A Reliable and Energy Balanced Routing Algorithm (REBAR) for UWSN

In [18] REBAR is proposed. REBAR is location based routing protocol and specially designed for energy consumption, data delivery ratio and handling of void problem. REBAR uses the sphere energy depletion model for energy consumption for sensor nodes in underwater environment. REBAR further extends the sphere energy depletion model for node mobility to balance the energy consumption; which prolongs the network lifetime. In REBAR, nodes broadcast in a specific domain between source and sink using geographic information since network-wide broadcast causes high energy consumption. This shows that the size of the broadcast domain is critical and REBAR resolves the size of broadcast domain with distance parameter between source and sink to balance the energy consumption among the nodes.

3. PERFORMANCE ANALYSIS

In this section we focus the performance of proposed routing protocols. The performance analysis is based on merits and demerits of the localization based routing protocols. The merits and demerits of the proposed routing protocols are shown in Table 1. The performance analysis also based on the comparison of different parameters from localization based protocols' operation. We have considered the parameters like: Hop-by-Hop or End-to-End, protocols have used single sink or multiple sinks, on which assumptions the proposed protocols are based, the proposed protocols have used the single entity or clustered based architecture, and whether the protocols are using the hello or control message or not. The detailed description is mentioned in Table 2.

Table 1. Merits and limitations of Localization Based Routing Protocols

Protocol	Merits	Limitations
VBF	a. A first approach towards the UWSN research. b. VBF network is consists on highly dynamic for the position of the nodes. c. VBF self-adaption algorithm is depends on 3D environment. d. VBF is scalable, robust and energy efficient protocol.	a. Sparse deployment of nodes. b. Radius threshold of routing pipe can affect the routing performance. c. Around the routing pipe, some nodes are involved frequently for forwarding; this kind of repetition will exhaust the battery power of these nodes.
HH-VBF	a. It defines per hop virtual pipe for each forwarder. b. Every intermediate node makes decision about the pipe direction based on its current location. c. HH-VBF significantly produces better results for packet delivery ratio, especially in sparse areas compared to VBF.	a. Threshold of Routing pipe Radius can affect the routing performance. b. Hop-by-hop approach utilizes the more signaling power.
FBR	a. In FBR the routing protocol, MAC and physical layer functionalities are tightly coupled by power control. b. Its system performance was evaluated with different node densities and network loads. c. Its performance conditionally involved with multicast queries. d. It performance is better than VBF.	a. Nodes become sparse due to the water movement and die earlier; this can affect the forwarding process. b. It is possible that candidate's nodes for hop may not involve in forwarding mechanism. c. Frequently use of RTS will increase the communication overhead and will affect the data delivery ratio in sparse area. d. Network flexibility will be affected due to the fixed sink nodes.
DFR	a. It relies on packets flooding technique which increases the reliability. b. Due to its flooding zone approach, it increases the probability of the successful delivery over one hop links. c. Node mobility and delivery ratio is increased in compare of VBF. d. It has less communication heads in comparison of VBF. e. It has also short end-to-end delay in comparison of VBF.	a. Due to the flooding the consumption of network resources will be increased. b. Void regions can be increased if source node cannot find the hop. c. Distance between nodes will also affect the overall performance. d. Void regions cannot be fully removed by BASE-ANGLE mechanism.
SBR-DLP	a. Reliability is improved as duplicate packets are delivered towards multiple sinks through multiple paths. b. Involvement of all nodes in mobility will increase the data delivery ratio. c. SBR-DLP overcomes on collision avoidance through its designed algorithm. d. The SBR-DLP simple location prediction mechanism will enhance the data delivery ratio.	a. Redundant transmission can increase the problems for underwater environment. b. Almost duplicate copy of DFR. c. Sector-based approach is more complicated than other routing protocols for UWSN. d. Deployment of sensor nodes will affect the overall performance. e. Deployment of 2D approach is not suitable for underwater environment.
LASR	a. Enhanced version of DSR and MANET routing protocols. b. Network performance is improved through the link quality mechanism. c. Operate effectively under high network loads. d. Compensate the high latency of acoustic link.	a. Almost duplicate copy of DSR and MANET. b. No appropriate network size defined by LASR. c. Simulation parameters are not authentic. d. Underwater environmental parameters are not considered in well manner. e. No comparison has been adapted with the famous underwater routing protocols.
REBAR	a. Controlled node mobility b. Balanced Energy consumption. c. Reliable data delivery. d. Constrained broadcast ranges. e. Increased network life time and data delivery ratio in comparison of VBF. f. Avoids the void regions.	a. Limited Network size has been adapted. b. Removal of void regions is not defined in real scenario for underwater environment. c. Concentration is only on energy level but real underwater parameters are avoided. d. Packets forwarding mechanism is not suitable for forwarding.

Table 2. Comparison Localization based Routing Protocols through different Parameters

Protocol	Year	Hop-by-Hop/ End-to-End	Requirements/ Assumptions	Cluster or Single entity	Hello or Control Message	Single Sink or Multiple Sink
VBF	2006	End-to-End	Location Information	Single entity	No	Single-Sink
HH-VBF	2007	Hop-by-Hop	Location Information	Single entity	No	Single-Sink
FBR	2008	Hop-by-hop	Location Information	Single entity	Yes	Multi-Sink
DFR	2008	Hop-by-Hop	Location Information	Single entity	No	Single-Sink
SBR-DLP	2009	Hop-by-Hop	Geo. Location is available	Single entity	Yes	Single-Sink
LASR	2006	End-to-End	N/W with special setup	Single entity	Yes	Single-Sink
REBAR	2008	Hop-by-hop	Location Information	Single entity	No	Single-Sink

4. CONCLUSION

In this review paper we have described the localization based routing protocols. The review article focuses the basic localization based models. We have described the basic operation of the proposed routing protocols with its basic architecture, route development, data forwarding mechanism, and route maintenance mechanism. We also have focused the merits and limitations of the proposed routing protocols from its basic operation. The review article also focuses the comparison of localization based routing protocols through different parameters like: hop-by-hop or end-to-end delay, requirements or assumptions, clusters or single entity, multiple sink or single sink, and hello or control message. From basic operation we observed the performance of FBR routing protocol is better than other proposed protocols.

REFERENCES

[1] Y. Bayrakdar, N. Meratnia, and A. Kantarci, "A comparative view of routing protocols for underwater wireless sensor networks", in *OCEANS, 2011 IEEE-Spain*, 2011, pp. 1-5.

[2] N. Ilyas, N. Javaid, Z. Iqbal, M. Imran, Z. A. Khan, U. Qasim, *et al.*, "AAEERP: Advanced AUV-Aided Energy Efficient Routing Protocol for Underwater WSNs", in *Advanced Information Networking and Applications (AINA), 2015 IEEE 29th International Conference on*, 2015, pp. 77-83.

[3] P.V. Amoli, "An Overview on Current Researches on Underwater Sensor Networks: Applications, Challenges and Future Trends", *International Journal of Electrical and Computer Engineering,* vol. 6, p. 955, 2016.

[4] S. Climent, A. Sanchez, J.V. Capella, N. Meratnia, and J.J. Serrano, "Underwater acoustic wireless sensor networks: advances and future trends in physical, MAC and routing layers", *Sensors,* vol. 14, pp. 795-833, 2014.

[5] 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 (IJECE),* vol. 6, 2016.

[6] S. Umar, P.D.P. Rao, and S. Gutta, "Tree Based Energy Balancing Routing Protocol by Self Organizing in Wireless Sensor Networks", *International Journal of Electrical and Computer Engineering,* vol. 5, 2015.

[7] A. Wahid, S. Lee, D. Kim, and K.S. Lim, "MRP: A Localization-Free Multi-Layered Routing Protocol for Underwater Wireless Sensor Networks", *Wireless Personal Communications,* vol. 77, pp. 2997-3012, Aug 2014.

[8] A. Wahid, S. Lee, and D. Kim, "A reliable and energy-efficient routing protocol for underwater wireless sensor networks", *International Journal of Communication Systems,* vol. 27, pp. 2048-2062, Oct 2014.

[9] K. Chen, Y. Zhou, and J. He, "A localization scheme for underwater wireless sensor networks", *International Journal of Advanced Science and Technology,* vol. 4, 2009.

[10] S.K. Dhurandher, M.S. Obaidat, and M. Gupta, "Providing reliable and link stability-based geocasting model in underwater environment", *International Journal of Communication Systems,* vol. 25, pp. 356-375, 2012.

[11] P. Xie, Z. Zhou, N. Nicolaou, A. See, J.H. Cui, and Z.J. Shi, "Efficient Vector-Based Forwarding for Underwater Sensor Networks", *Eurasip Journal on Wireless Communications and Networking,* 2010.

[12] P. Xie, J.H. Cui, and L. Lao, "VBF: Vector-based forwarding protocol for underwater sensor networks", *Networking 2006: Networking Technologies, Services, and Protocols; Performance of Computer and Communication Networks; Mobile and Wireless Communications Systems,* vol. 3976, pp. 1216-1221, 2006.

[13] N. Nicolaou, A. See, P. Xie, J. H. Cui, and D. Maggiorini, "Improving the robustness of location-based routing for underwater sensor networks", *Oceans 2007 - Europe,* Vols 1-3, pp. 1485-1490, 2007.

[14] J.M. Jornet, M. Stojanovic, and M. Zorzi, "Focused beam routing protocol for underwater acoustic networks", in *Proceedings of the third ACM international workshop on Underwater Networks*, 2008, pp. 75-82.

[15] D. Hwang and D. Kim, "DFR: Directional Flooding-Based Routing Protocol for Underwater Sensor Networks", *Oceans 2008, Vols 1-4*, pp. 922-928, 2008.

[16] 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.

[17] E.A. Carlson, P.P. Beaujean, and E. An, "Location-aware routing protocol for underwater acoustic networks", in *OCEANS 2006*, 2006, pp. 1-6.

[18] J.M. Chen, X.B. Wu, and G.H. Chen, "REBAR: A Reliable and Energy Balanced Routing Algorithm for UWSNs", *GCC 2008: Seventh International Conference on Grid and Cooperative Computing, Proceedings,* pp. 349-355, 2008.