TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 9020 - 9026

A Review on Routing Protocols and Deployment Challenges Concerning Underwater Wireless Sensor Network

Swati A Gandhi
PhD Research Scholar, RajashreeShahu College of Engineering Research Centre, Tathawade, Savitribai Phule Pune University, Pune, MH, India.

Prof. S. S. Sonavane,
Professor, Indira College of Engineering and Management, Pune, SavitribaiPhule Pune University, Pune, MH, India.

Article Info
Volume 82
Page Number: 9020 - 9026
Publication Issue:
January-February 2020

Article History
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 09 February 2020*

Abstract:
Autonomous underwater vehicles (AUVs) are the technological advancement possessing tremendous application potential in monitoring real-time maritime activities. Many of the applications make use of sensor nodes deployed at different depth in the interested region. The node beneath the water communicates with node near water surface using multi-hop communication assisted by suitable routing protocols. However, the communication is governed by environmental constraints. Also, there are issues like large propagation delay and limited link capacity. The pipe blockage removal application is one such application where environmental conditions are dynamic. Therefore, there is need to pay significant attention to construct reliable scheme and resource aware efficient routing protocol between the source and the sink node. Here, we present the broad review on issues concerning underwater pipe blockage removal and compare various routing protocols reported in recent literature. The study mainly aims at comparing the available routing protocols, test beds, simulation platforms, and analysis tools available with research community.

Keywords: *Under water wireless sensor network, routing protocol, deployment strategies.*

I. Introduction

Currently, the wireless sensor network (WSN) is more reliable than before with the advancement in peer to peer network management using grid and cloud computing. The prime element in WSN is sensor node. The sensor nodes are tiny and inexpensive with intelligence and are connected either in ad-hoc or self-configuring networks. These nodes communicate the information from the influential wireless link to the link, which is either terminated at the data console or to other networks [1]. The WSN was originally meant for military applications for enemy movement navigation [2] and currently deployed in many industrial applications for forecasting, monitoring and controlling. The vivid industrial applications of WSN technology have a potential of billion-dollar market. However, this technology requires advancement and evolution in standards, protocols and compatibility to newer applications [3] with less design complexity.

The WSN can be classified on the basis of application as pre-deterministic and randomly unattended networks. The unattended networks are

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those deployed in critical environment and have restricted or limited human supervision. The non-exhaustive list of critical environment for these WSNs restricting to under water are lake monitoring, offshore navigation, oil exploration, sea-quakes, cable and pipe monitoring and blockage detection etc. The underwater WSN (UWSN) consists of mesh of sensor nodes, tiny processor, storage chip and communication capabilities working together to monitor application of interest. However, for efficient deployment of WSN for under water communication needs robust design of network services and protocol. The current research in radio frequency (RF) based WSN is needed to more focussed towards UWSN, as the characteristics of acoustic channel beneath the water, low bandwidth, high noise, Doppler spread, dead zones, path losses andlong and dynamic propagation delay. Also, the aqua environmental properties such as viscosity, temperature and sediments play the vital role in the design of UWSN. Therefore, UWSN is more challenging than conventional WSN. In UWSN, the communication link quality is impaired aqua temperature and morphology of water at the bottom. In this review article, we survey the current state of art research in protocols used in UWSN and various deployment strategies and challenges concerning UWSN.

The review article is organised as follows. In section 2, we discuss and compare state of art latest protocols used in UWSN. In section 3, the various deployment strategies and their channels in deployment is discussed. The concluding remark and future research direction in UWSN is presented in section 4.

II. Routing Protocols

USWN is considered as one of the way to explore and monitor under water territory. Nov *et al.*[4] in their study have considered 3D void of the underwater demography. The float has a sensor node which monitors the depth of the water. Many floats form the network and transmit the information in the form of packets. The void aware pressure routing (VAPR) protocol decides the packet forwarding based on depth measured at each node. The VAPR is also called *depth based routing* (DBR) protocol which was originally proposed by Yan *et al.*[5] in the year 2008. The VAPR is however Omni-sink node and packet takes only one hop during transmission. The routing protocols can be conventionally classified as localization and localization free routing protocol. For sensor node localization mainly *vector based forwarding* (VBF) protocol [6] is used. In VBF method the source node draws a vector connecting to the sink node. The nodes which lies near the vector transmits the packets towards the sink node. The nodes lying on the vector are pipeline nodes. However, the VBF is based on the assumption on the localization principle which itself is atrocious and pivotal. Therefore, wahid*et al.*[7] in their further research has *hop by hop vector based forwarding* (HHVBF). It follows the same method of vector drawing as VBF but HHVBF precomputes the routing vector at each hop starting from source node, piping node towards the sink node. The re-computation reduces the sparse density problem.

The hop by hop dynamic addressing based protocol (H^2-DAB) was proposed by Ayaz and Abdullah [8] for under water monitoring. The network is multi-sink architecture having nodes with water buoys for collecting data on the water surface. There are also some nodes beneath the water employed at various water levels and few nodes are anchored at the bottom. The advantage of using H^2-DAB protocol is that it increases the per hop delivery ratio in dense as well as sparse networks. Also, the protocol is energy efficient with small propagation delay. The very straight forward and energy saving protocol is focussed beam routing (FBR) protocol [9]. In these kinds of networks, the source node sends radio transmission signal and the nearest node reply back with an acknowledgement. If the receiving node do not acknowledge then transmission packet power is increased. Many times

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classical protocol is not suitable for UWNS as they may lose signal in between. Therefore, hybrid routing protocol is proposed by Han *et al.*[10] called power efficient routing (PER). The PER works in two phases. In first phase forwarding node is selected and in next phase forwarding tree is trimmed. The forward path is established by tracing the duplicate packet received by the sensor node. The PER has limitations of wanting the information of all neighbouring node to forward the packet and then trim. The comparison of all the protocols surveyed is shown in the table 1. The comparison is done by considering parameters as number of hops, number of sink nodes, parameter of protocol and range.

Table 1: Routing protocols in last decade.

Protocol Name	**2D/3D**	**Progress area**	**Sink (1/Many)**	**Hops (1/Many)**	**Tx/Rx/ Tx-Rx**	**Parameter**	**Range (m)**
VAPR[4]	3D	Inner layer	1	1	Tx	Distance	30
HHVBF [7]	3D	Pipeline virtual	1	Multi	Rx	Distance	100
VBF [6]	3D	Pipeline virtual	1	Multi	Rx	Distance	20
FBR [9]	2D	Cone	Multi	1	Tx	Distance	NA
PER [10]	3D	Distance	1	Multi	Tx	Distance	100
DFR [11]	2D	Angle	1	Multi	Rx	Distance	500
H^2-DAB [8]	3D	Lower Address	Multi	1	Rx	Address	500
DBMR [12]	3D	Lower Depth	Multi	1	Tx	Depth	100
Hydro-Cast [13]	3D	Lower Depth	Multi	Multi	Rx	Depth	250
EEDBR [14]	3D	Lower Depth	Multi	Multi	Tx	Energy	250

III. UWSN deployment strategies

In under water WSN, deployment of sensor node is very crucial and challenging because deployment scheme may be cost effective and increase the detection capability of WSN. It can also enhance the monitoring quality by expanding the coverage area. The through literature survey makes us to categorise the deployment strategies into four different objectives namely coverage maximization, enhanced connectivity, energy and lifetime optimization and multi-objectivity.

IV. Coverage maximization

Coverage maximization is one of the significant functionality indicator as it is associated with the sensing field which measures the sensor field supervision. Covering more area in less expenses is challenging particularly in UWSN. This is because navigation area is undefined and crucial. The maximum coverage strategies are mainly popular mathematical optimization techniques viz; ant colony, glow-worm swarm, genetic algorithm and hole detection and healing. The comparison of these coverage maximization strategies is given in table 2.

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Table 2: Comparison of various coverage maximization strategies.

Author	Optimization Algorithm	Sensor type	Advantage	limitation
Liu and He [15]	Ant Colony-greedy based	Fixed and Homogenous	Cost effective and energy efficient	Cost increase with addition of nodes.
Yourim and Yong [16]	Genetic Algorithm	Heterogeneous	Wide coverage	Unsuitable for mobile nodes
Liao and Kao [17]	Glow-worm swarm	Mobile	Decentralised control	Oscillatory
Yang and Wu [18]	Hole detection and healing	Mobile and homogenous	Simple, less sensor movement	Issues with border holes

V. Enhanced connectivity

The connectivity plays a pivotal role in lurid environment such as under water currents, temperature, viscosity etc. The connectivity is assumed to be prime factor in deployment strategy. It can also be treated as a deployment constraints [19]. The connectivity optimization strategies are also mathematical optimization techniques with constraints. The comparison of various enhanced connectivity reported in state of art is tabulated in table 3.

Table 3: Comparison of various enhanced connectivity strategies.

Author	Optimization Algorithm	Sensor type	Advantage	limitation
AI-Turjman[20]	3D deployment with lifetime constraint	Probabilistic	Cost effective for 3D harsh scenario	Network partitioning for intolerant functional node availability
AI-Turjman[20]	Genetic algorithm	Binary	Unpredictable communication range	Node failure due to obstacles and limited range
Seddik[21]	Standard semi-definite programming	Disk model	Implemented through UAVs	Reconnection not possible for disconnected network
Hassanein[22]	Optimal 3D grid	Binary or spherical disk	Offline and early deployment	Low life span

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VI. Energy efficiency and lifetime optimization

An energy consumption is another vital challenging issue in WSN due to constraint on node energy. The batteries of buoy nodes are possible to replace but for under water nodes replacement is not possible [23]. Generally, WSNs are battery powered and recharging of the batteries is impractical, therefore network life span depends upon battery life. One of the possible to increase the life expectancy of node is to preserve the sensor energy. Due to limited battery life, WSNs are to be designed for effective utilization of the limited battery power. The comparison of various energy efficiency strategies reported in literature are tabulated in table 4.

Table 4: Comparison of various energy efficiency strategies.

Author	Optimization Algorithm	Sensor type	Advantage	limitation
Halder[24]	Heterogeneous node	Stochastic	Less delay and low packet loss	QoS needs improvement for 2D area
Restuccia[25]	Dual Beacon discovery	Binary	Best in unpredictable arrival time	Less efficient in curvilinear scenario
Restuccia[26]	Swarm intelligence	Binary	Scalable	More efficient algorithm needed
Tiegang[27]	Non uniform load routing	Binary	Energy wastage, less cost	Not suitable for lurid environment

VII. Multi-objectivity

Many of the researchers have made efforts to achieve the objectives of area coverage, energy consumption, life span, connectivity and magic number of sensor deployment. However, to fulfil the objectives the problem was modelled as a single objective function with constraints. The multi-objectives approach of modelling is used by few researchers which is tabulated in table 5.

Table 5: Comparison of various multi-objectivity strategies.

Author	Optimization Algorithm	Sensor type	Advantage	limitation
Lin and Zhiyun[28]	Online incremental	Homogenous and mobile	Autonomous deployment	Total deployment time optimization required
Sengupta[29]	Multi-objective evolutionary	Homogenous and fixed	Application in probabilistic event detection	Node increases energy consumption also increases
Pradhan and Panda[30]	Particle swarm	Stochastic and binary	Simple implementation	Obstacles are not considered

VIII. Conclusion

In this review article, the routing protocol and deployment strategies are thoroughly reviewed. The second section deals with various protocols and their comparison for UWSN. The hydro-cast and EEDBR protocols are highly recommended for UWSN in lurid environment. These two protocols are recommended because they are multi-sink and multi-hop with wide coverage. The scope of deployment has been presented in another section. For measuring the scope, the deployment strategies were categorized into four types viz; coverage maximization, enhanced connectivity, energy and lifetime optimization and multi-objectivity. Here, the though literature review is presented in the form of comparative tables on the basis of optimization algorithm used, sensor model and its type, advantage and limitations. It has also been shown here that diverse strategies might be applicable in vivid scenes in UWSN. While choosing amongst the various strategies the trade-off between connectivity and coverage is necessary. Here, it is worth to recommend that multi-objective strategies are best suitable in ambiguous UWSN environment.

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