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Citation: Khalid, Muhammad, Ullah, Zahid, Ahmad, Naveed, Arshad, Muhammad, Jan, Bilal, Cao, Yue and Adnan, Awais (2017) A Survey of Routing Issues and Associated Protocols in Underwater Wireless Sensor Networks. Journal of Sensors. p. 7539751. ISSN 1687-725X (In Press)

Published by: Hindawi

URL: https://www.hindawi.com/journals/js/aip/7539751/ <https://www.hindawi.com/journals/js/aip/7539751/>

2017; **00**:1–16

REVIEW ARTICLE

A Survey of Routing Issues and Associated Protocols in Underwater Wireless Sensor Networks

Muhammad Khalid [1]* Zahid Ullah[1], Naveed Ahmad [2], Muhammad Arshad[1], Bilal Jan[3], Yue Cao[4] and Awais Adnan [1]

[1] Institute of Management Science (IMS)Peshawar, Pakistan
[2] University of Peshawar, Pakistan
[3] Sarhad University of Science Technology, Peshawar
[3] Northumbria University, Newcastle upon Tyne, UK

ABSTRACT

Underwater Wireless Sensor Network is newly emerging wireless technology in which small size sensors with limited energy, limited memory and bandwidth are deployed in deep sea water and various monitoring operation like tactical surveillance, environmental monitoring and data collection are performed through these tiny sensor. Underwater Wireless Sensor Network is used for exploration of underwater resources, oceanographic data collection, flood or disaster prevention, tactical surveillance system and unmanned underwater vehicles. Sensor node consist of small memory, central processing unit and antenna. Underwater network is much different from terrestrial sensor network as radio waves cannot be used in Underwater Wireless Sensor Network. Acoustic channels are used for communication in deep sea water. Acoustic Signals carries with itself many limitation. Such as Limited bandwidth, higher end to end delay, network path loss, higher propagation delay and dynamic topology. Usually these limitation results in higher energy consumption with less number of packets delivered. The main aim now a days is to operate sensor node having smaller battery for a longer time in network. This survey has discussed the state of the art Localization based and Localization free routing protocols. Routing associated issues in the area of Underwater Wireless Sensor Network has also been discussed. Copyright © 2017

KEYWORDS

Underwater; Sensors; Routing; Localization based; Localization free Energy efficiency; Survey

***Correspondence**

Department of Computer Science, Institute of Management Science Peshawar, Pakistan

Email: khaleedmohammad90@gmail.com

1. INTRODUCTION

Underwater Wireless Sensor Network (UWSN) is a newly emerging wireless sensor technology which is used to provide the most promising mechanism and methods that are used for discovering aqueous environment. it is used in various key application in underwater environment. It works very efficiently in many situation like commercial, military, emergency monitoring, data collection and environmental monitoring purposes. In this kind of networks, small sensors node are deployed in sea water. These nodes are equipped with central processing unit, antenna and battery. Batteries in these sensor nodes are non rechargeable and non replaceable. These sensor collect the required data and send it to sink which are installed offshore [1]. Autonomous Underwater and unmanned Vehicles which are equipped with sensors that are specially designed for underwater communication [2], which are mostly used in areas where exploration for natural resources. These resources lies underwater , unmanned vehicle gather data of these resources and send it back to off shore sinks which is forwarded to other stations for further processing [3] [4]. Radio waves cannot be used in underwater communication therefore acoustic communication is needed [5]. Communication through acoustic links are very costly as compared to radio link. Acoustic links have high end to end delay and low bandwidth. Once data packet is received at sink then it is forwarded through radio waves to other sinks and base stations [6]. Underwater networks has very limited resources in comparison to terrestrial wireless sensor networks. Protocols suites that are used in other networks cannot be directly applied to underwater networks [7]. Till date many protocols has been proposed for underwater sensor networks. These are mainly divided into two types which are localization based and localization free protocols [8]. Where the term localization means, knowledge of nodes and sink in network. Those routing protocols which need prior geographic information of other nodes and sink are localization based routing protocols while those routing protocols which does not need any earlier geographic information for routing can be categorized as localization free routing protocols [9] [7].

The rest of the paper is organized as follow. Section 2 discussed the architecture of terrestrial wireless sensor network. In section 3, the architecture of underwater wireless sensor network is explained. Section 4 has defined the related work. While Localization based and Localization free routing protocol are discussed in section 5 and 6 respectively and finally conclusion is drawn in section 7.

2. TERRESTRIAL WIRELESS SENSOR NETWORK

Wireless sensors network is newly emerged technology, whose purpose is to perform monitoring tasks in different fields of operation as well as to take necessary actions according to received data and instructions [10]. WSN is used in Military purposes, security monitoring, flood monitoring, Health monitoring, border monitoring and many more [11]. WSN consist of small sensor nodes and sinks. Sensor are battery operated having small memory, transceiver and receiver that are used to send and receive data [12]. Sinks are usually supplied external power and use to collect data from sensor. A sink in WSN is considered as data center which collect data from all sensors and forward it to other base stations. Nodes in WSN are deployed from plane which adopts a random topology. To make efficient communication between nodes, energy efficient routing protocols are needed. A few routing protocol that are used in WSN are discussed below.

In various applications of WSN, deployment of sensor nodes is performed in adhoc fashion and no precautions for deployment stage is used. Whenever it is deployed then sensor nodes must be able itself to self organize itself with a wireless communication network system. As Sensor nodes are battery-operated and these nodes are expected to continue its operation for a relatively long period of time [13]. In many of the cases it is usually very difficult and almost even impossible to change batteries or recharge it. WSN carry many limitations with itself like, high level of unreliability of the sensors, limited battery power, low memory, network control and management functions, network security, localization and synchronization. Several shortcomings has been observed using traditional routing protocols and are because of energy constraint nature of such networks [14]. Like, in flooding technique a node sends data received by it to all nodes in the network and this process repeats itself at every node until data is reached to sink [14]. It is observed that this technique does not take into account the level of energy consumption. So we encounter the problem of receiving multiple copies at the end node and much energy is consumed during this process [15]. As already mentioned that flooding is blind technique and packets get duplicate and also circulate in the network, so this will lead towards implosion problem [14]. When two sensor are in the same region so they will sense the same data and ultimately they will forward the same data and in result duplicate copy of same packet will be generated [16]. To overcome the problem of flooding and duplication of same packet another technique called gossiping can be applied. In this kind of process when a sensor sense data, it simply forward packet to one of their neighbors by selecting them randomly and without any kind of mechanism. This process continues until packet reaches the sink. The main problems that is faced during gossiping are end to end delay and path loss. As only one packet is forwarded so if the packet is dropped at any sensor then data will be lost. Also there is not specialized mechanism whether data is moving in right direction or not. Below are few famous routing protocol used in wireless sensors networks.

2.1. Low-Energy Adaptive Clustering Hierarchy

Low-energy adaptive clustering hierarchy (LEACH) is considered to be most popular hierarchical routing protocol [12]. LEACH form multiple clusters based on received signal strength and a cluster head is chosen through election or direct selection. This selected cluster head will pass on data to sink. Data is then forwarded to other cluster heads and finally delivered to sink. LEACH is known as the first and the most popular energy-efficient hierarchical clustering algorithm designed for WSN which was suggested for reduced power consumption during routing in WSN. Using LEACH the task of clustering is rotated among nodes which is based on duration during communication. In LEACH protocol a cluster head can directly communicate with the base station and can send data directly to base station. For the purpose of long network life time and long term monitoring, all the cluster heads work together and work in a group. To work for long time and make the network alive and operational for a longer period of time. First of all a cluster head is elected according to the rules defined by the protocol. After election, one node is selected as cluster head. After selection of cluster head when a node in a cluster sense some data, it simply forward it to cluster head and then that cluster forwards it to another cluster head and ultimately it reaches it destination or sink. There are multiple kind of operation and mechanism taken into consideration while performing network operation. Like RTS/CTS is performed before forwarding data to any node in the network [12].

2.2. Power-Efficient GAthering in Sensor Information Systems

Power-efficient GAthering in Sensor Information Systems (PEGASIS) is routing protocol for WSN [17]. Unlike LEACH it doesn't form any cluster. PEGASIS developed a chain like route from end node towards sink, that it used to send data to sink. PEGASIS uses hop by hop mechanism to forward data to sink. PEGASIS was an earlier extension of LEACH which actually forms a chain instead of forming clusters which were formed in LEACH. The mechanism of its working is quite simple in which it develop a chain. In this chain a single node is selected from nodes through which data is forwarded and the same process is repeated until it reaches sink. Hence data is gathered at every node and forwarded to next node. While performing chain construction, greedy algorithm is adopted. In PEGASIS it is also assumed that every node has all the information about the network. Using greedy approach it does not take into account any energy efficiency mechanism. Hence some nodes are used very frequently and dies very early. Every time this protocol forms a different topology.

2.3. Threshold Sensitive Energy Efficient Sensor Network

Threshold Sensitive Energy Efficient Sensor Network TEEN [18] is a routing protocol which is used for responsive networks where a fast response is required. It is used in such application where data is critical and each and every packet happens to be very useful. It also forms clusters where a cluster head sets a hard and soft threshold for packet forwarding. It consumes less amount of energy as compared to other protocols. TEEN set a threshold for data forwarding. This threshold is sensed by other nodes nodes. The draw back in this scheme is that if threshold is not reached then it will not communicate with each other.

3. UNDERWATER WIRELESS SENSOR NETWORKS

UWSN is a wireless technology which has gained world wide attention these days. It provides the most promising mechanism used for discovering aqueous environment very efficiently for many scenarios like military [19], emergency and commercial purposes. Autonomous Underwater and unmanned Vehicles which are equipped with sensors that are specially designed for underwater communication, which are mostly used in those areas where exploration for natural resources which lies underwater is needed [20]. These unmanned vehicle gather data of resources lying underwater and send is back to off shore sinks which is forwarded to other stations for further processing. Radio waves cannot be used in underwater communication therefore acoustic communication is used. Once data packet reaches sink then it is forwarded through radio waves to other sinks and stations [3].

Underwater wireless sensor environment is much different from that of terrestrial. Acoustic waves are used in underwater communication while terrestrial network uses radio waves [4]. Normally the problems that are occurs during communication in underwater communication are due to dense salty water, electromagnetic as well as optical signal does not work in UWSN [6]. Due to high attenuation and absorption effect, signals cannot travel long distances [21]. Hence to overcome these problems, acoustic communication is used. It can overcome these problem and provides a better transfer rate in underwater environment [6]. Using acoustic communication propagation speed lowered down from speed of light to that of sound speed which is 1500m/sec. Due to lower speed there is usually long propagation delay and higher end to end time [22]. In acoustic communication bandwidth is very limited which is less than 100KHz [1]. In underwater scenarios sensor nodes are usually considered static but it is also considered that they may move from 1 to 3 meter/second because of flow of water [71]. Sensor nodes used in underwater network are battery operated and it is almost impossible to replace its batteries. In underwater applications a multi-hop or multipath network is required and data is forwarded by passing all nodes towards sink. Once data is received at any of the sink then data is forwarded to concerned node through radio transmission [23]. Figure 1 represents network architecture of UWSN.

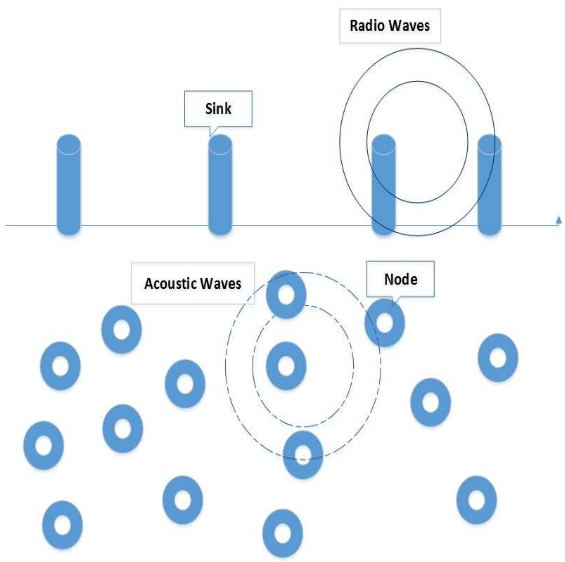

Figure 1. Network Architecture

While using those routing protocols which requires higher bandwidth [24], usually has higher delay at the node's end. As it is known that acoustic communication does not support higher bandwidth so using routing protocols that are used in terrestrial network will not perform good due to it higher delay and high energy

Figure 2. Routing Protocols in UWSN

consumption [25]. Using underwater network, topology does not remains the same as node moves due to flow of water [26]. In localization based protocol, geographical network information is necessary so it possess more control messages than localization free protocol, in which no prior network information is necessary [27]. Fig. 2 shows the start of the art localization based and localization free routing protocols in UWSN.

Oceans are vast and covers around one hundred and forty millions square miles, which is more than 70 percent of Earth total surface, Not only it has been considered to be major source of the nourishment, but with span of time its taking a good role in transportation stuffs, defense as well as adventurous purposes and natural resources presence [28]. All its importance towards humanity, it is very strange that a very little of about Earth water bodies is known [29]. Less than ten percent of whole ocean volume is investigated, while a large amount of area has still not been explored. The increase in roles of the oceans in the lives of humans [30], importance of these largely unexplored area has got a lot of importance [31]. On one hand the traditional approaches for underwater monitoring have got several disadvantages while on the other side human presence is not considered to be feasible for underwater environment [32].

3.1. Node Architecture:

A general architecture of underwater wireless sensor node is composed of five main elements. Which are energy management unit, data sensing unit, depth measuring unit, communication unit and central processing unit [33]. As show in fig. 3

Processing unit is responsible for all kind of data processing which energy management unit has the responsibility to manage the remaining energy of the node and consumption of energy in run time [34]. Data sensing unit is used to sense data. It always remains active even when node is in sleep mode [35]. Communication unit is responsible for all kind of data communication whereas depth measuring unit is used for measuring depth of nodes when it is deployed in sea [14].

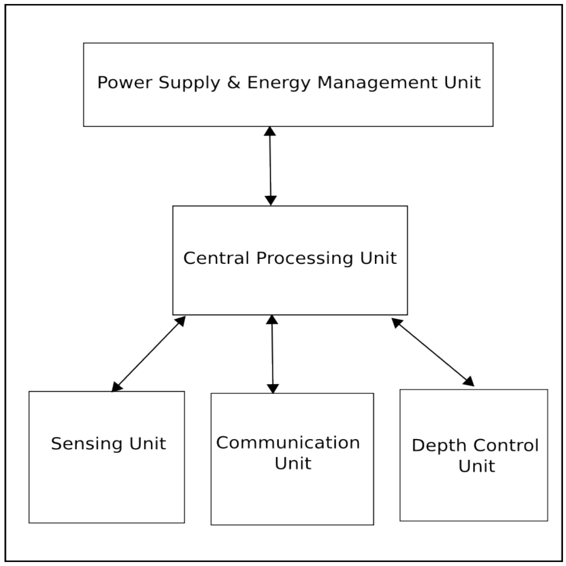

Figure 3. Architecture of a typical underwater sensor node

3.2. Constraints in Underwater Wireless Sensor Network

UWSN carries multiple differences in comparison with terrestrial area network. Where nodes are stable or move in a specified direction while in underwater networks they usually displaces their positions with the flow of water. Acoustic communication is used for underwater transmission which minimizes the bandwidth for data transferring. A few constraints are discussed below.

- Limited Bandwidth
  Acoustic channels offer very limited amount of bandwidth, as Radio transmission cannot be used for underwater communication [3]. Acoustic communication requires more energy to send a small amount of data, due to its lower bandwidth.
- Propagation Delay
  Due to use of acoustic communication, propagation speed becomes five times slower than that of radio frequency i.e. 1500m/sec [4].which obviously results in high propagation delays in the network.
- Limited Energy
  Nodes that are used in underwater communication are larger in size [3], hence they require larger amount of energy for communication. Furthermore, acoustic channels also required more energy for communication than terrestrial network. Batteries

in UWSN cannot be recharged or replaced therefore use of energy efficient communication is always a need to provide network with higher life time.

- Limited memory
  In UWSN nodes are small in size and therefore they have a limited amount of storage and processing capacity [6].
- Variable Topology
  UWSN does not have a specific or static topology as flow of water make it difficult for node to remain static in one place, therefore node moves randomly.

4. RELATED WORK

F. Akyildiz in [3], discussed architecture of acoustic communication. 2D and 3D underwater communication has also been discussed. They also discussed different layers of communication in underwater networks. Multiple open researched has been provided in this survey paper. However discussion about routing protocol in underwater networks and their comparison has not been discussed. In [22], Jun-Hong Cui discussed the differences between terrestrial and underwater network. Like in UWSN, low bandwidth, propagation delay, high bit error rate, floating of node and limited energy has been discussed. Multiple unique characteristics of UWSN their benefits and flaws were discussed. Similarly no proper discussion about routing protocols has been carried out. While in [15], Muhammad Ayaz explained the basis architecture of underwater networks. Multiple schemes of routing in underwater communication has been discussed in this survey. They also discussed multiple routing protocols. Detailed diagrams were presented to get a good understanding of different routing protocols but still no comparison were carried out. Vijay Chandrasekhar in [23], has discussed the term localization. Localization is a phenomenon in which the location of node is already known to other nodes and sink. Which make it easier for sink to locate and communicate it. Multiple schemes like area based scheme, area localization scheme and hop count based scheme has been discussed [36]. In Energy Efficient Dynamic Address Based routing (EE-DAB)[37] every node is assigned node id, s-hop id and c-hop id. Node id show the physical address of node, s-hop id consist of two digits which show how many hops away one or two sinks are. Left hop is considered as highest priority and is selected as primary route. The C-hop id also consist of 2 digits which show that how many hop the receiving nodes are away from courier nodes. acoustic communication uses more energy than that of radio communication. As wireless sensor nodes are battery operated and higher energy consumption lead towards a serious problem. Thus energy efficiency has become a major problem in underwater wireless sensor networks. In [38], a delay tolerant protocol is proposed which is called delay-tolerant data dolphin scheme. This proposed scheme is designed for delay tolerant systems and applications. In this protocols all the sensing node stay static and data sensed by static nodes are passed on to data dolphin which acts a courier nodes. So in this methodology high energy consumed hop by hop communication is avoided. Data dolphins which acts a courier nodes are provided with continuous energy. In the architecture all the static nodes are deployed in the sea bed. These static sensor goes into sleep mode if there is no data to sense and it periodically wakes up when it sense some data. After sensing some kind of desired data it simply forward this data to courier nodes which are also called data dolphins. These data dolphins take this data and deliver it to base station or sink. The number of dolphin nodes depend upon the kind of network and its application and the number of nodes deployed in the network. In [39], a virtual sink architecture is proposed where sinks are connected with each other through radio communication. In this scheme, each and every sink broadcast a hello packet which is also known as hop count update packet. After receiving hello packet by nodes, a hop count value is assigned to every sensor. These hop counts are used for selection of forwarding nodes while sending data packet from one node to another. However the proposed scheme has a few limitations which includes redundant transmission i.e. transmission of a same packet multiple times. A detail comparison of routing protocol is provided in I .

5. LOCALIZATION BASED ROUTING PROTOCOLS

Routing protocols which needs prior network information before send any data over the network are called localization based routing protocols. These protocol usually need geographical information of all node in the network as well as information about sink location. These protocols are considered to be less energy efficient most of energy is wasted in collecting their geographical information. These records are updated dynamically after fixed interval of time as node's position may changes due to water flow. Routing protocols basically need the assumption of sensor nodes in underwater sensor networks [36] . In localization based routing protocols a node need the information of all the network nodes as well as of sink like in this scenario prior network information is needed for a node [71], [2], [33]. In [38], Focused Beam routing protocol requires geographical information of itself and as of destination. It uses RTS/CTS mechanism to forward data. Sender protocol transmit the RTS and receiver of the packet send back CTS. In Vector Based Forwarding [48], a source node develop a vector based routing pipe starting from sender node towards sink. Various times it is hard to find an available node in the routing pipe for data forwarding. SBR-DLP [42], also known as sector base routing, with destination location prediction is a localization based routing algorithm where

Table I. Comparison of Routing Protocols in UWSN

Protocol	methodology	Energy Consumption	Geographic information	Communication overhead	Packet copies	Control packets	sink	Multi-path	performance	Publication year
VBF [40]	Use a single virtual pipeline for data forwarding	High	Required	High	Multiple	No	Single	No	Low	2006
Multipath virtual sink [35]	mitigates the near sink contention by defining a group of spatially diverse physical sinks.	Medium	required	low	multiple	yes	multiple	Yes	Medium	2006
Resilient Routing [41]	Backup path are optimally configured by relying on topology	Low	Required	Medium	Single	No	Single	Yes	Medium	2006
LASR[42]	Works on link quality metrics	Medium	Required	Medium	Single	Yes	Multiple	Yes	Medium	2006
HH-VBF [43]	Multiple virtual routing pipes used simultaneously	Low	Required	Medium	Multiple	No	Multiple	Yes	High	2007
ICRP [44]	Works on reactive routing mechanism	Medium	Not Required	Medium	Multiple	No	Single	No	Medium	2007
DUCS [45]	Uses data aggregation scheme to eliminate redundant information	Low	Not Required	Low	Single	Yes	Multiple	Yes	Medium	2007
Packet cloning [46]	exploits node proximity and their ability to overhear one another.	High	Required	Low	Multiple	Yes	Multiple	Yes	Medium	2007
DDD [38]	Nodes stay static, sensed data is forwarded to courier nodes	Low	Not Required	Low	Multiple	Yes	Multiple	Yes	High	2007
MCCP [47]	selects a set of non-overlapping clusters from all potential clusters	Low	Required	High	Single	Yes	Single	Yes	Low	2007
DBR[27]	Forwards data to nodes having lower depth.	High	Not required	Low	Yes	No	Multiple	Yes	Medium	2008
FBR [48]	Route is dynamically established as the data packet traverses the network towards its final destination	Low	Required	High	Multiple	Yes	Single	Yes	Medium	2008
DFR [49]	Works on packet flooding technique to increase reliability	High	Not required	Low	Multiple	No	Single	Yes	Low	2008
REBAR [50]	An adaptive scheme for setting up data propagation range	Low	Required	Low	Multiple	Yes	Multiple	Yes	High	2008

Protocol	methodology	Energy Consumption	Geographic information	Communication overhead	Packet copies	Control packets	sink	Multi-path	performance	Publication year
EUROP [51]	Decrease number of transferring packets in network	Medium	Required	Low	Single	Yes	Single	Yes	Low	2008
UW-HSN [2]	A hybrid approach for radio and acoustic communication	Medium	Required	High	Single	Yes	Multiple	Yes	Medium	2008
Multisink opportunistic [52]	Packets are sent simultaneously over spatially diverse paths	High	Not Required	Medium	Multiple	Yes	Multiple	Yes	Low	2008
LCAD [33]	Avoid multi hop communication by forming clusters	Medium	Required	High	Single	Yes	Multiple	No	Medium	2008
H2-DAB [53]	Applies dynamic addressing based scheme on all nodes in the network	Low	Not Required	Medium	Single	Yes	Multiple	No	Medium	2009
SBR-DLP [54]	Divide whole networks in sectors	High	Required	High	Multiple	Yes	Single	Yes	Yes	2009
TCBR [55]	Requires equal energy consumption for all nodes	High	Required	High	Single	No	Single	No	Low	2010
E-PULRP [56]	Select immediate rely nodes on the fly	Medium	Required	High	Multiple	Yes	Single	Yes	Medium	2010
QELAR [57]	Making residual energy of the network more evenly distributed	Low	Not Required	Medium	Multiple	Yes	Multiple	Yes	High	2011
RMTG [58]	Uses greedy forwarding and previous hop hand shaking	High	Not Required	High	Single	No	Single	Yes	Low	2011
E-DAB [37]	Uses efficient dynamic addressing based scheme	Low	Not required	High	Single	Yes	Multiple	No	Low	2012
EE-DBR [39]	Take in to account depth as well as residual energy	Medium	Not Required	Medium	Multiple	Yes	Multiple	Yes	Medium	2012
LAFR [59]	Link detection and adaptive routing feedback system is deployed	High	Required	High	Multiple	Yes	Single	Yes	Medium	2013
MRP [60]	Data is collected through multiple mobile sinks from nodes deployed in 3D fashion	Low	Required	Low	Multiple	Yes	Multiple	Yes	High	2013
VAPR [61]	Uses sequence number, hop counts and depth information for data forwarding	High	Required	Low	Multiple	Yes	Single	Yes	Medium	2013

Protocol	methodology	Energy Consumption	Geographic information	Communication overhead	Packet copies	Control packets	sink	Multi-path	performance	Publication year
DS-DBR [62]	formulate delay-efficient Priority Factors and Delay Sensitive holding time	Medium	Not Required	Medium	Multiple	No	Multiple	Yes	High	2014
RDBF [63]	Utilize a fitness factor to measure and judge the degree of appropriateness for a node to forward the packet	High	Required	Low	Single	No	Multiple	No	High	2014
DVRP [64]	sensor nodes in the network make a local decision of data packets forwarding under the constraint of the flooding angle between them and energy status	High	Not Required	High	Multiple	No	Single	Yes	Low	2014
CARP [65]	exploits link quality information for data forwarding	High	Required	High	Single	Yes	Single	Yes	High	2015
SEDG [36]	Optimal assignment of member nodes with Gateway Nodes	High	Required	Medium	Multiple	Yes	Multiple	Yes	Low	2015
HPFB [66]	Proposes a harmonic potential field based routing protocol for 3D underwater sensor networks with local minima	High	Required	Low	Single	Yes	Single	No	Medium	2016
Hydro-Cast [67]	A hydraulic pressure-based any cast routing protocol	Medium	Not Required	High	Single	No	Single	Yes	Low	2016
AFB [68]	Network coding-based protocol is proposed in order to make a better use of the duplicates	High	Not Required	Low	Multiple	Yes	Multiple	Yes	Medium	2016
AREP [69]	Each node maintains a neighbour table in which items are used to analyse the link state	Medium	Required	High	Single	Yes	Single	Yes	High	2017
ECBCCP [70]	Confidence level of the sensor nodes is computed to select the optimal relay nodes	High	Required	Medium	Multiple	Yes	Single	Yes	Medium	2017

node is not needed to have information of its neighbor nodes. It only need to carry its own information and pre-planned movement of sink although it decreases the flexibility of the network and it will only move around in a scheduled manner. Table II provides a detailed overview of localization based routing protocols in UWSN.

5.1. Vector Based Forwarding

Vector based forwarding (VBF) [40] is a routing scheme which require maintenance and frequent recovery of routing paths. This is a position based routing protocol in which a very less amount of nodes are actually involved in routing process. Therefore a very less number of nodes play their role in the operation of data forwarding. As being the very important phenomenon in routing which is data forwarding where very less number of sensor nodes take part in this data forwarding operation. In this scheme a sensor already know its location and location of the destination. It is also considered that a node already know all the node that are involved in the routing process or forwarding of a node. Which includes the source node, forwarding intermediate nodes and the final node or the destination. The idea of this protocol is based on virtual routing pipe and all forwarding data is sent through this pipe. As routing pipe phenomenon is involved in this scheme so most of the time nodes that are used during routing process are the nodes that lies in the area of the pipe.

5.2. Hop by Hop – Vector Based Forwarding

. Hop by Hop – Vector Based Forwarding HH-VBF [43] is an advanced version of VBF. In this scheme main focus is on robustness and problems faced by its earlier version [40]. Same concept as was used in VBF is also used here. Concept of virtual pipe is deployed here. But here instead of single virtual routing pipe which is used by VBF, single routing pipe is used for every forwarder which means a single pipe for every forwarding hope. As we observed that only a few nodes are involved in VBF while in HH-VBF multiple routing pipes are created. Which ultimately result in lower end to end delay and higher energy efficiency. Using this mechanism every node can make a decision about the direction of pipe which is based on node's current location.

5.3. Directional Flooding-Based Routing

Directional Flooding-Based Routing (DFR) [49] is Localization based routing protocol. In DFR, flooding phenomenon is used where packet is send through flooding mechanism to final destination. In this protocol it is assumed that every node must know the location of itself and one hop away node and final destination. Only a limited number of nodes takes part in routing process.In this scheme the flooding zone is decided by in between FS and FD. Where S is source node and D is destination node while F is receiving node usually sink.

5.4. Location-Aware Source Routing

Location Aware Source Routing (LASR) [42] is an advanced version of DSR. Link quality metrics and location awareness technique is used by LASR routing scheme. Earlier protocol only depended upon shortest path metrics and in the end it lead towards bad performance.

5.5. Focused Beam Routing

Focused Beam Routing (FBR) [48] is localization free routing protocol, in which sender node knows only its own location information and location information of final destination. No further geographical information of other nodes is necessary which results in less control messages and high throughput. The mechanism that FBR has adopted for data forwarding is that next hop is selected keeping in view final destination.

First of all an RTS packet is multicast in its neighbors, which contains location of sender and final destination. This multicast operation is performed at low power level. If sender does not receive any response then level is increased.

Figure 4 , explained data forwarding method which is used in FBR. Where node A has a data packet that is required to send to the destination node which is D. To complete this operation, node A has to multicast a request in order to send (RTS) packet to its neighboring nodes which lies in its range. As this RTS packet contains the location of node A and that of final destination D. Initially, this multicast action will be performed at the lowest power level, which can be increased if neither of the node is found as next hop in the transmission range. For this purpose they define a finite power levels, which is P1 through PN. In FBR if no node lies in senders range then it has to rebroadcast RTS which result in consumption of high energy.

5.6. Directional Flooding-Based Routing (DFR)

DFR [49] is location based routing protocol. In DFR, flooding phenomenon is used where packet is send through flooding mechanism to final destination. In this protocol it is assumed that every node must know the location of itself and one hop away node and final destination. Only a limited number of nodes takes part in routing process. In this scheme the flooding zone is decided by in between FS and FD. Where S is source node and D is destination node while F is receiving node usually sink.

5.7. Location Aware Source Routing

Location Aware Source Routing [42] is an advanced version of DSR. Link quality metrics and location awareness technique is used by LASR routing scheme. Earlier protocol only depended upon shortest path metrics and in the end it lead towards bad performance.

Table II. Comparison of Localization Based Routing Protocol

Architecture	Technique	Performance metrics				Knowledge Required
		Packet Delivery Ratio	Multiple Sinks	Energy Efficiency	Packet Overhead	
VBF [40]	Based on Localization, Geographic routing scheme	Low	N	Fair	High	Whole Network
HH - VBF [43]	hop by hop, geographic routing algorithm	Fair	Y	Low	Medium	Whole Network
FBR [48]	Route is being established dynamically in this distributed algorithm	Fair	N	High	High	Own and sink Location
DFR [49]	Directional flooding routing approach	Fair	N	Low	Medium	Own, sink and one hop neighbor
LASR [42]	Link quality metrics and location awareness technique	Fair	Y	Fair	Medium	Own and sink Location
SBR - DLP[54]	Sector based routing with destination location prediction	Low	N	Fair	High	Movement of sink and own locaion

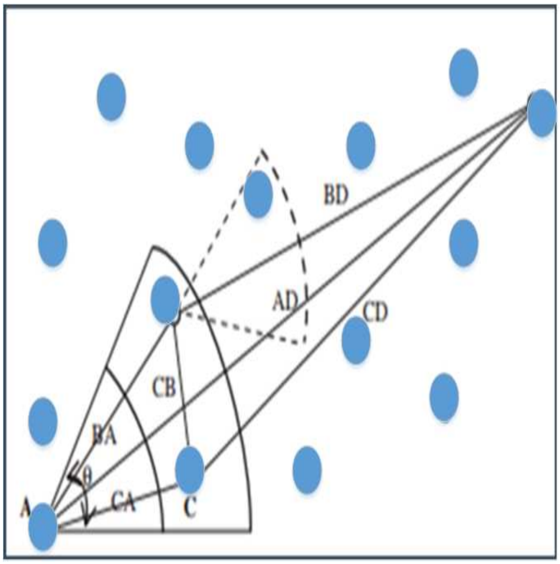

Figure 4. Working of FBR Protocol

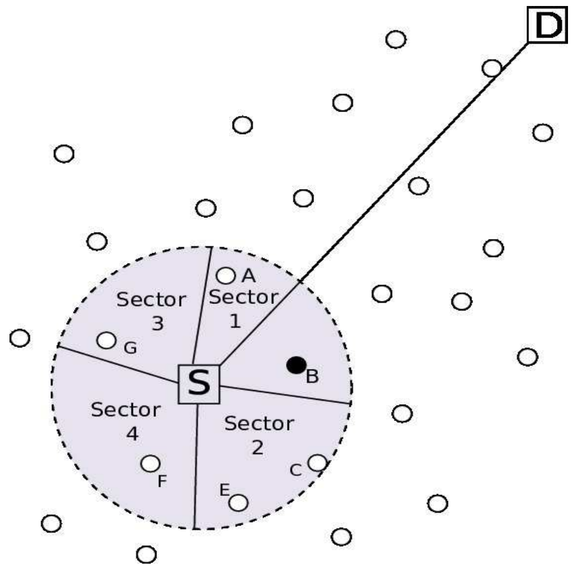

Figure 5. Forwarder selection at the sender (SBR-DLP)

5.8. Sector Based Routing with Destination Location Predication

In UWSN many Localization based routing algorithm has been introduced and it is considered that network with already know geographical location of other nodes improve energy efficiency. It helps in minimizing control messages and network overhead. SBR-DLP [54], is a Localization based routing protocol. In this protocol not only other nodes but destination nodes are also considered to be mobile. In SBR-DLP sensor does not need to carry information about neighbors. In this algorithm it is considered the every node must know its own location information and pre-planned movement of destination nodes. Hop by hop mechanism is used to forward data to destination nodes. In Fig. 5 a node S having data packet that is needed to be send to the destination D. In order to do so, nex hop is found by broadcasting a Chk_Ngb packet which has its current location as well as it node id. The neighbor node which will receives Chk_Ngb, whether it is near to destination node D. The nodes that meet these conditions will reply to the node S by sending a Chk_Ngb_Reply packet.

6. LOCALIZATION FREE ROUTING PROTOCOLS

This category includes those routing protocols which does not require any earlier geographical information of the network. These protocols perform their operation without having location information of other nodes.

In these kind of routing protocols, a sensor node does not require any prior network information of other network nodes [72], [73] . Most of the localization protocols work on flooding phenomenon and are considered to have fast packet delivery ratio and low end to end delay [10], [11].

In Depth Based Routing protocol [27], pre network information is not needed. It just take the depth of sensor nodes into account and forward a packet. It actually compares the depth of sending node with that of receiving node so if depth of sender node is higher than that of receiver node then it will forward the data otherwise it will ignore that node.

Similarly in [39], Energy Efficient DBR, it take into account the depth information as well as residual energy of the node at the time of sending data.

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6.1. Depth Based Routing

Many routing protocol in UWSN needs geographic location of the nodes in order to communicate. Localization itself requires much energy and calculations. Depth Based Routing Protocol (DBR) [27] does not need any earlier information. DBR need depth information of each node. When a node with the highest depth sense some movement, it starts sending data to higher nodes, such that it compares its depth with neighbor nodes. If send packets to only those nodes whose depth is lower than sender node. The same process continuous until packet is received by sink. This protocol is mainly concerned about depth of node. Sink are provided with continuous power.

Fig. 6 defines next node selection in depth based routing protocol. Where three nodes n1, n2 and n3 are in communication range of sender S. In first step depth of receiver nodes is checked. N1 and N2 are found eligible for data forwarding as their depth is less than sender node S.

DBR does not take into account any other parameter then depth, which leads towards a few drawbacks. Network life of network where DBR is used, will be less as it will always send data to the same higher node as no check has been observed. This will lead to death of the node. Path selection in DBR has no proper mechanism, as no proper strategy is used for efficient or short path selection.

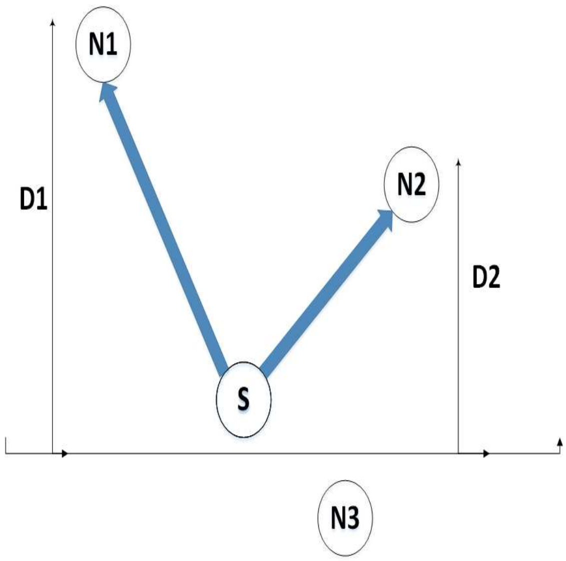

Figure 6. Node selection in DBR

6.2. Energy Efficient Depth Based Routing

In Energy Efficient Depth Based Routing (EE-DBR) [39], protocol when a node forwards its data, it takes into account the depth of the receiver node and its residual energy. When a node forwards data it first compares the depth of the receiver node with itself, if the depth of receiver node is smaller than sender then it checks the residual energy of receiver node. Node with higher residual energy and less depth among the neighbors is selected as next hop for communication. Every node has information on depth and residual energy about their neighbors, so the node with most suitable parameter is selected for communication.

EE-DBR has not defined any mechanism for multi-path communication. A node may forward data to node which is far away from sender and will results in higher energy consumption. Similarly no parameter has been taken into account to define a shortest and efficient path towards sink.

6.3. Hop by Hop – Dynamic Addressing Based

In Hop by Hop-Dynamic Addressing Based routing (H2-DAB)[53] , dynamic addresses are assigned to nodes and destination ID is set to “0” for all nodes. No pre-network information is required in this protocol. In first step of network setup, a hop id is assigned to each node. Every node in the network will have two type of addresses, node id and hop id. Node id is physical address of node while node id changes with change in location.

Table III. Comparison of Localization Free Routing Protocol

Architecture	Technique	Performance metrics				Knowledge Required
		Packet Delivery Ratio	Multiple Sinks	Energy Efficiency	Packet Overhead	
DBR [27]	Only depth information needed for comparison in routing	High	Y	Low	Low	No network information required
EEDBR [39]	Compare depth as well as routing while performing routing operations	Low	Y	Fair	Medium	One hop neighbor
H2-DAB [53]	Assigns dynamic addresses to all nodes in the network	High	N	Fair	Low	One hop neighbor
EE-DAB [37]	Assigns dynamic addresses and those addresses are compared during routing	Fair	Y	Fair	High	One hop neighbor and Sink
DDD [38]	Sensing nodes stay static and data sense by them are forwarded to courier nodes	Low	Y	High	Low	Presenance of Dolphins Nodes

Hop ID's are assigned from top to bottom. Node having lower depth are assigned lower hop id, like node which is nearest will have hop id of 1. Similarly nodes having higher depth are assigned higher hop ID's. H2- DAB supports multi sink architecture, where multiple sink are installed on shore. Those sinks are connected with each other through radio communication. Data packet received at any sink is considered received.

However this approach might create problems where a node cannot find in range, any node which has lower hop id from sender node. In case of failure at finding suitable node in first attempt, sender will re-transmit data packet and then wait again for specified amount of time. If results were still the same then sender node will forward data to a node having nearly or equal hop id as sender node. This process results in energy wastage.

6.4. Energy Efficient Dynamic Addressing Based Routing

In Energy Efficient Dynamic Address Based routing (EE-DAB) [37]. In this type of dynamic addressing scheme, every node is assigned node id, s-hop id and c-hop id. Node id show the physical address of node, s-hop id consist of two digits which show how many hops away one or two sinks are. Left hop is considered as highest priority and is selected as primary route. The C-hop id also consist of 2 digits which show that how many hop the receiving nodes are away from courier nodes. Fig. 7 describes how to make the selection of nodes for sending data packets. As source node N23 is having a data packet, with their own HopIDs 66 & 99 (CHopIDs for all the nodes are 99 because of non-availability of Courier node in the area); A simple query message will be send asking neighbor nodes about their HopID. In its reply an Inquiry Reply packet is send back to sender node which contains only three fields i.e. Node-ID, S-HopID and C-HopID of replying nodes. Where Nodes N15, N16, N22, N24 and N25 lies in communication range and will reply with their Node-ID and HopID. After receiving, N23 sort out these Inquiry replies and get the minimum HopID. As diagram shows, nodes N15 and N16 are declared as the candidates for the Next Hop, because both of them have smaller HopID as compare to HopID of the source node but N15 qualify for this competition because of its backup link which is also smaller than N16. The source node will forward the data packet with N15 Node-ID as a Next Hop. In other cases, if two nodes respond with the same minimum HopID then the node who replied earlier will be selected as next hop for further communication.

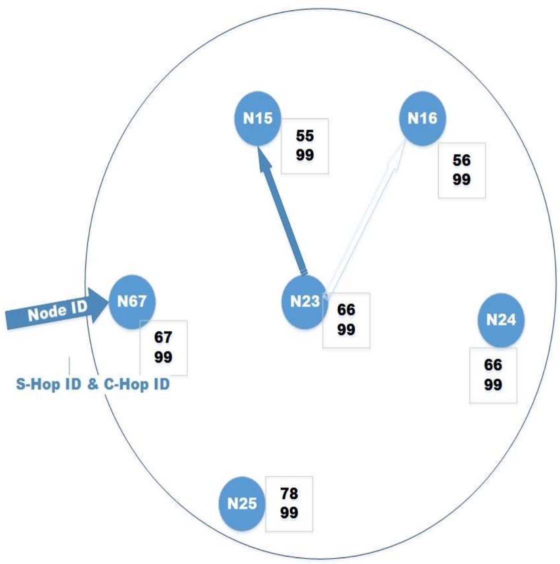

Figure 7. Hop Selection EE-DAB

6.5. Mobile Delay Tolerant Routing

As acoustic communication uses more energy than that of radio communication. As wireless sensor nodes are battery operated and higher energy consumption lead towards a serious problem. Thus energy efficiency has become a major problem in underwater wireless sensor networks. In [38], a delay tolerant protocol is proposed which is called delay-tolerant data dolphin scheme. This proposed scheme is designed for delay tolerant systems and applications.

In this protocols all the sensing node stay static and data sensed by static nodes are passed on to data dolphin which acts a courier nodes. So in this methodology high energy consumed hop by hop communication is avoided. Data dolphins which acts a courier nodes are provided with continuous energy. In the architecture all the static nodes are deployed in the sea bed. These static sensor goes into sleep mode if there is no data to sense and it periodically wakes up when it sense some data. After sensing some kind of desired data it simply forward this data to courier nodes which are also called data dolphins. These data dolphins take this data and deliver it to base station or sink. The number of dolphin nodes depend upon the kind of network and its application and the number of nodes deployed in the network.

7. CONCLUSION

In this survey, state of the art routing protocols in UWSN has been presented. Almost all routing protocl in UWSN is presented in tablur form. UWSN environment is very different as compare to terrestrial wireless sensors network. Acoustic channels consume a large amount of energy with very less amount of data transferred. Furthermore, the flow of water make it quite difficult for sensor nodes to forward data in a stable scenario. Routing in UWSN is considered to be very important part in respect of energy efficiency. Among all defined protocols above, one cannot be selected the best because every protocol has some cons and pros. As a newly emerging technology, a lot of work has to be done with respect to energy efficiency, end to end delay, propagation delay and path loss. Energy efficient routing schemes plays a vital role in extending life time of network and efficient path selection for data forwarding. Keeping in view the limitations in UWSN, energy efficient schemes are encouraged. Underwater sensors are used in multiple application scenarios and separate mechanism is adopted when proposing a new routing scheme. In recent years, routing in UWSN has attracted a large number of researchers in this area. Still this area carries certain challenges like topology management, energy efficiency, data retransmission and path loss, which needs researcher's attention.

COMPETING INTERESTS

The authors declare that there are no competing interests.

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