International Journal of Computational Intelligence Systems
Vol. 12(2), 2019, pp. 1526–1536
DOI: https://doi.org/10.2991/ijcis.d.191203.001; ISSN: 1875-6891; eISSN: 1875-6883
https://www.atlantis-press.com/journals/ijcis/

Special Issue

Energy Analysis on Localization Free Routing Protocols in UWSNs

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ARTICLE INFO

Article History

Received 19 Sep 2019
Accepted 01 Dec 2019

Keywords

Localization free Routing protocols
Underwater wireless sensing network
Energy Analysis

ABSTRACT

The challenges faced in underwater communication systems are limited bandwidth, Energy consumption rate, larger propagation delay time, End-End Delay (E-ED), 3D topology, media access control, routing, resource utilization and power constraints. These issues and challenges are solved by means of deploying the energy efficient protocol. The protocol can either be localization-based protocol or localization free protocol. In this paper, review of localization free protocols were discussed and reviewed with reference to environmental factors, data transmission rate, transmission efficiency, energy consumption rate, E-ED and propagation delay. The review analysis gives the pros and cons to give rise to the new directions of research for future improvements in Underwater Wireless Sensor Networks (UWSNs). This manuscript propose a survey on localization free protocol according to the problem addressed or the major parameter considered during routing in UWSNs. Unlike the existing survey, the present survey focuses on present state and art of routing protocols, in terms of routing strategy issues addressed. The solutions of energy efficient protocol is arrived by highlighting the pros of each protocols. The description of routing strategy for each protocol is presented to understand its operation in an understandable form. The cons of each protocol is taken into consideration for further investigation and to arrive the best protocol. The presented routing strategy, pros and cons provide open challenges and research directions for future investigation.

ACRONYMS

UWSN	Underwater Wireless Sensor Networks
USBL	Ultra Short Base Line
SBLS	Short Base Line System
LBLS	Long Base Line System
DPSN	Data Packet Switched Network
DCS	Data Communication System
LF-IEHM	Localization Free Interference and Energy Holes Minimization Routing
EECOR	Energy Efficient Cooperative Opportunistic Routing
EEDBR	Energy Efficient Depth-Based Routing Protocol
UWCS	Underwater Wireless Communication Systems
SSR	Signal Strength Received
DEAC	Depth and Energy Aware Cooperative Routing Protocol
EEIRA	Energy Efficient, Interference And Route Aware
DBR	Depth-Based Routing
ODBR	Optimized Depth-Based Routing
DSRP	Delay Sensitive Routing Protocol
EBECRP	Energy Efficient And Balanced Energy Consumption Cluster-Based Routing Protocol
E-CARP	Enhanced Channel-Aware Routing Protocol
WDFAD-DBR	Weighting Depth And Forwarding Area Division DBR Routing Protocol
F-LQE	Fuzzy logic-based link Quality Estimator
QERP	Quality-Of-Service (Qos) Aware Evolutionary Routing Protocol
RIAR	A Reliable And Interference Aware Routing Protocol
VBF	Vector-Based Forwarding
DRADS	Depth And Reliability Aware Delay Sensitive (*DRADS*) *Routing Protocol*
DBR-MAC	Depth-Based Routing Aware Mac Protocol
CARP	Channel-Aware Routing Protocol
EBPR	Energy Balanced Pressure Routing
EHRDBR	Energy Hole Repairing Depth-Based *Routing Protocol*
NEFP	Novel Efficient Forwarding Protocol
DREE	Distance Based Reliable And Energy Efficient (DREE) Routing Protocol
BMOOR	Balanced Multi-Objective Optimized Opportunistic Routing
RSS	Received Signal Strength
EnOR	Energy Balancing Routing Protocol
DUOR	Depth-Based Underwater Opportunistic Routing Protocol
Co-UWSN	Cooperative Energy Efficient Protocol For UWSN
t_{pd}	Propagation Delay
E-ED	End-End Delay
RE-PBR	Reliable and Energy efficient Pressure-Based Routing Protocol

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1. INTRODUCTION

Localization in underwater communication system (UCS) is a topic of great attention and study with progressively starving applications driving the need for improved solutions. Numerous systems are feature with an increased inertial navigation method. The inertial navigation method uses tracking and filtering approaches to provide improvements on traditional navigational equipment's. Apart from tracking and filtering approach, several localization techniques are available based on acoustic signaling.

Also, we can usually classify the localization systems depending on the External Acoustic System Baseline Length as Ultra Short Base Line (USBL): <10 cm, Short Base Line System (SBLS): 20–50 m, Long Base Line System (LBLS): 100 m–10 km.

Figure 1 shows the structure and coordinate system of surface buoy position and transponder position. The first localization technique based on acoustic signaling is LBLS in which the transponders are fixed at sea level and the underwater system cross-examines the transponders for round-trip delay approximation.

The localization in case of LBLS is accurate, but this method of localization technique needs longer calibration time. The second localization technique is SBLS in which the primary ship moves above the underwater vehicle system.

The localization in case of USBL is a method of acoustic positioning in underwater communication system. The complete system consist of transceiver, transponder/responder. The communication takes place from underwater to the sink is by means of acoustic waves. The acoustic pulse is transmitted and received by transceiver and is detected by means of transponder. The USBL system measure the time between the transmitting and receiving of the acoustic signal by the transceiver. The measured time is converted into range and the USBL calculates both the time and angle from transceiver to transponder. The LBL and SBL identify the position by the measurement of multiple-distances, whereas the USBL measure the distance from transponder by single run-time and target-direction by measuring the phase-shift of the return signal.

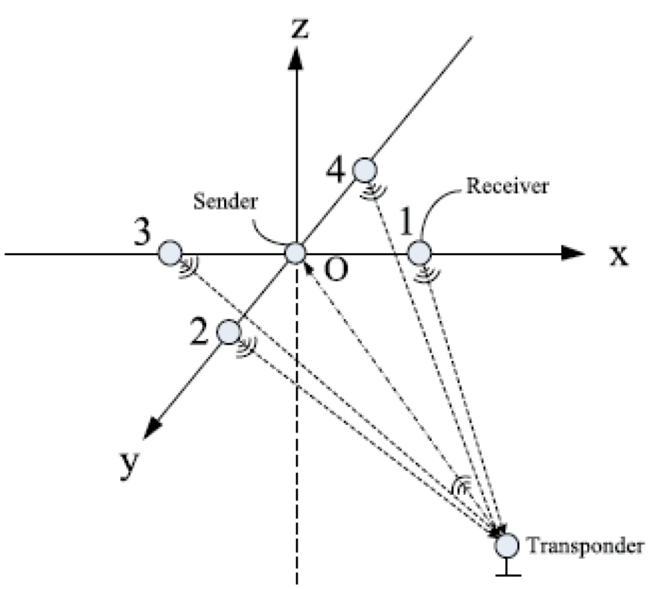

Figure 1 Acoustic array coordinate [Surface Buoy positions = transponder positions].

The third localization technique is floating buoy. Above the reference point of the buoy surface the technique acts similar to that of lLBLS. Several localization techniques have been proposed that consider the underwater nodes rather single/small group of nodes.

1.1. Challenges and Issues

Reliable transfer of data from source to destination is guaranteed by overcoming the intrusion and energy holes in Underwater Wireless Communication Systems (UWCS). The inherent challenges faced in UCSs are

1. Low bandwidth
2. Larger t_{pd} than radio-frequency communication
3. Inadequate bandwidth
4. Design of interference and energy holes minimization in routing protocols
5. Communication among nodes
6. High bit error rate
7. Energy consumption rate
8. Power constraints
9. 3D topology
10. Media access control
11. Routing and resource utilization
12. Consistency and effectual utilization of acoustic communication link
13. Optimum packet size selection for communication
14. Distributed localization

The issues and challenges in UCS like consistency and effective use of acoustic communiqué link, optimum selection of size of the data packet for communication, distributed localization, power consumption, ecological effects, media access control and the protocol used for network routing requires input from research and community to address the above said issues and challenges in UCS.

1.2. Main Reference Schemes in Previous Survey

The routing protocol in underwater sensing network involves generation of nodes with zero energy transmission and causes interference in transmitting the data packets. Interference causes collision in Data Packet Switched Network (DPSN) and losses occur in Data Communication System (DCS). The routing traffic and losses in underwater communication system are unbearable.

The battery power operating the sensor nodes causes practical limitations. Therefore, Energy optimization is important factor in Underwater Wireless Sensor Networks (UWSN). This is achieved by Localization Free Interference and Energy Holes Minimization Routing (LF-IEHM) routing protocol [1]. This protocol handling these issue deliver reliable and flexible data transmission and it's essential in time sensitive and military applications.

The underwater acoustic sensing network is important to gather the data from aquatic environments as underwater acoustic sensor is faced with different challenges such as high energy consumption, propagation delay, and low bandwidth. Therefore, energy constraint is important in forwarding the DPSN from source to destination without loss in energy. Energy Efficient Cooperative Opportunistic Routing (EECOR) protocol is used to forward the packets toward the surface sink [2]. The challenges faced in USWN's are larger amount of t_{pd}, inadequate bandwidth, and high bit error rate. It is difficult to design short propagation delay and highly efficient protocol.

To address this, issue a protocol based on signal strength received (SSR) is utilized instead of location based protocol. In SSR, the sensor node first creates a vector from node to sink and the length indicates the beacon signal from sink. A node is created near to the vector and this has been given the highest priority to be a candidate for the next-hop. Void-avoiding algorithm is used to avoid data packets being delivered to the nearby nodes. The use of SSR reduces the energy consumption and reduces the End-End Delay (E-ED) [3].

Figure 2 shows the clustering of various nodes in which the SSR can be understood. The data transmission in UCS takes place between nodes available in underwater system and sink. When there is no clustering between the nodes the SSR at the sink will be week as the data loss happens while transmitting. If cluster nodes are created the data from underwater system is transmitted to cluster node 1 and from cluster node 1 to cluster node 2 and likewise it goes on till the data is transmitted from source node to sink node. This is how the data loss can be avoided and SSR can be strengthened between source node and sink node.

Underwater sensing networks are recently used to support time-critical aquatic applications such as submarine tracking and harbor monitoring. Hydraulic pressure unicast routing allow the sensor data reported to sonobuoys at sea level using acoustic sensor multi-hopping algorithm [4]. Fading is one of the common problems in underwater communication. Therefore, the effective means of data

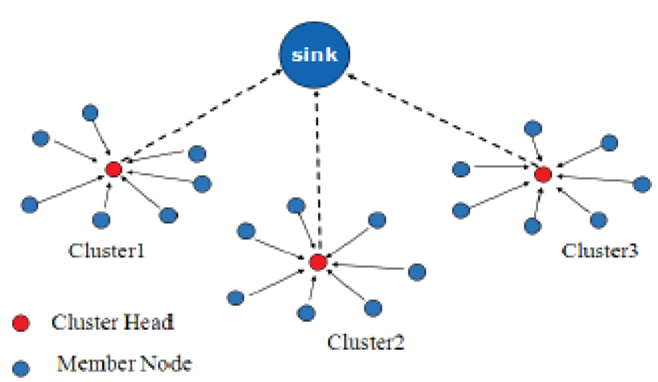

Figure 2 Signal strength received (SSR) from node to sink by clustering.

transfer is problem. To avoid this energy efficient routing with variable depth threshold protocol (DEAC) is utilized [5]. An application based routing protocol that works on delay sensitive application in underwater routing system. This gives large amount of impact on node mobility on the basic data transmission rate, energy consumption, E-ED and throughput performance in UWSN [6]. This have increased consideration from researchers due to their vast applications in military, commercial and environmental purposes.

UWSNs are extensively implied for marine aquatic atmosphere, pollution monitoring, military investigation, monitoring, disaster prevention and resource investigation. Inference aware routing protocol is used in USWN to follow end-end path from basis node to sink node. The problem of void hole in Depth-Based Routing (DBR) protocol is avoided in Inference aware routing protocol [7]. The protocol that combines the relay and direct forwarding mechanism in transmission of data from source node to sink node is utilized by means of Energy Efficient, Interference And Route Aware (EEIRA) protocol in USWN. This protocol provides better performance than DBR structure in terms of energy efficiency as it implies the best relay, reducing the number of hops and consequent follow up in shortest path to reduce channel losses [8,9]. The energy consumption is uniform in Optimized Depth-Based Routing (ODBR) scheme among other sensor nodes.

The sensor nodes are driven by battery power, with poor back-up and inadequate lifetime. It is impracticable to change batteries during the active communication. It is essential to stabilize the energy available against the energy usage, so as to increase the lifetime of the sensor node and the complete communication channel is able to accomplish its mission for a longer time [10]. The Depth and Energy Aware Cooperative Routing Protocol (DEAC) acts like solution provider protocol to improve data reliability and throughput. By incorporating cooperative routing technique throughput is achieved, just by negotiating the earlier node energy consumption and high energy consumption in later nodes. Also dying of more nodes is addressed at various depth thresholds in [11]. The Delay Sensitive Routing Protocol (DSRP) uses a dual path that carries the data in primary path with minimum delay and data in secondary path with maximum delay to achieve E-ED sequence [12]. In Reliable And Interference Aware Routing (RIAR) protocol each sensor node find its neighbor node within its transmission range and calculates the physical distance toward sink and hop-count sink. In data-forwarding phase the sender node select the next forwarder node based on cost function (CF) [13].

The Energy Efficient Interference and Route Aware Protocol combines direct and relay forwarding mechanism to transmit the DPSN from source node to sink node [14]. The Energy Efficient And Balanced Energy Consumption Cluster- Based Routing Protocol (EBECRP) improves the stability period and network lifetime. Balanced energy consumption is achieved by reducing the load near to sink node and the concept of clustering is used in this protocol [15]. ODBR scheme which ensures uniform energy consumption amongst sensor nodes and hence maximizes the data transmission [16]. Greedy hop packet forwarding strategy is utilized in Enhanced Channel-Aware Routing Protocol (E-CARP) for effective data transmission with the comparison done with the previously collected sensory data [17]. In Weighting Depth and Forwarding Area Division (WD-FAD) the next-hop forwarding node is selected based on the state of current node and failure in forwarding in local sparse region [18]. Physical distance is taken into account in Distance Based Reliable And Energy Efficient (DREE) protocol but has not been utilized. DREE utilizes Fuzzy logic-based link Quality Estimator (F-LQE) [19]. Cooperative energy efficient protocol is a nature of wireless medium and DPSN are transmitted in this by means of nearby sensor nodes as relay node [20].

1.3. Point of View in This Paper

In this paper we propose comparative analysis of protocol for UCS based on message broadcast from multiple surface nodes. The analysis is done to arrive for the energy efficient localization free protocol.

1.4. How to Compare The 20 Known Protocols

The multitude localization-based applications have been projected with Wireless Sensing Networks. There are Range-based localization scheme and Range-free localization scheme available for most of the networking applications. The limitations of hardware at sensing node avoid the usage of range-based localization structures that rely on absolute point-to-point distance estimation, and may produce fine-grained resolution but resides stern requirements on time synchronization and signal measurements.

The cost effective localization scheme is Range-free scheme and coarse accuracy is sufficient for most sensor network applications. This scheme doesn't require any distance or angle measurement among the nodes. The Range-free localization techniques are broad classified as "Local techniques" and "hop counting techniques." The comparison of below said protocol has to undergo an extensive research on state-of-the-art range-free localization schemes to recognize the desirable system configurations of each, consequence of location error on routing and tracking performance.

2. SURVEY METHODOLOGIES

2.1. Grouping of Protocols

2.1.1. Protocols addressing node mobility

DBR

DBR requires only depth information of the sensor nodes. Energy consumption by sensors used in USWN is non-uniform and hence additional nodes are created with zero transmission energy. Though alive nodes are available the DPSN do not reach the sink as additional nodes are created with zero transmission energy. The depth of water pressure at sensor nodes is utilized as forwarders selection parameter. The reduction in Network lifetime of DBR is due to the non-utilization of residual energy and depth information during data transmission from underwater sensor nodes to sink.

DSRP

The impact of node mobility for various underwater environmental conditions is examined in delay sensing routing protocol. The node mobility performance of DSRP is based on energy consumption, E-ED, data throughput, data transmission rate. This protocol uses two paths carrying primary path of minimum delay and secondary path of maximum delay to achieve E-ED sequence. From this a reduced packet error rate achievement is done and will limit the E-ED by increasing the data rate of source. The application specific DSRP protocol works on delay sensitive applications. In this the node and node mobility are implemented in a single source traffic application of the network. The node mobility effect on energy consumption, E-ED and throughput performance shows the effectiveness of the communication system.

2.1.2. Protocol addressing energy balancing

EEDBR

In case of EEDBR residual energy and depth information data are effectively utilized and this results in balanced energy consumption under various nodes, whereas the transmission of data redundant packets is reduced. The sensor node selects the forwarder node with its lowest depth and highest residual energy among the one-hop neighbor node. The energy hole in the network is avoided and balance in energy consumption is attained. If the link quality is not good the probability in data packet loss is increased.

ODBR

The ODBR assure uniform energy consumption and hence maximizes data transmission [16] at various sensing node and these nodes are driven by battery power with inadequate lifetime. Practically it is not possible to change the batteries during active lifetime. Therefore it is essential to stabilize the energy availability against the energy usage. The stabilization of energy prolongs the lifetime of the sensor nodes and the communication network is able to fulfill its mission for a longer time [10]. Energy efficiency is an important factor in underwater localization, which has to be focused for maximum data transmission.

EBECRP

The routing protocol in underwater sensing network involves generation of nodes with zero energy transmission and causes interference in transmitting the data packets. Interference causes collision in DPSN and losses occur in DCS. The routing traffic and losses in UCS are unbearable. The sensor nodes are operated by battery power which is limited. Energy optimization is important factor in USWN. The sensor nodes are powered by battery and the battery power is limited due to harsh water environment and replacement of battery is also expensive. This issue is addressed in [15] by means of energy efficient and balanced energy consumption cluster based routing protocol. In EBECRP the data collected are clustered and the channel collects the data from nodes in their vicinity and send that data as a single composite packet received at the sink. The EBECRP improves the stability period and network lifetime. Balanced energy consumption is achieved by reducing the load near to sink node. The concept of clustering is used to collect the data and forward the compressed data to sink if the energy consumption during data transmission is more than data receiving.

HYDROCAST

An acoustic sensor equipped with aquatic swarm causes drift in ocean current and enables 4D for effective monitoring of underwater events. Major issues faced under these situations are ocean current, limited bandwidth and limited energy resources. The HydroCast: Pressure Routing protocol addresses these challenges. Novel opportunistic routing mechanism is utilized to select sub-set of data forwarders that maximizes the data transmission status with limit in the co-channel interference. From [10] it is very clear that the HydroCast Protocol transmits maximum number of DPSN with reduced E-ED and increase in network lifetime. Data transmission efficiency is also increased with less energy consumption.

2.1.3. Protocols extenuating channel conditions

DEAC

The underwater environment is harsh and noisy. Fading is common and unavoidable while performing reliable data transfer. With the help of depth sensor, the depth of each node is calculated initially, flooding has been reduced by selecting a forward node called Depth (Dth) Threshold. This Dth having the capability of restricting the outgoing interfaces for incoming packet data. Based on the neighbor sensor node the Dth will be performed. The role of Dth is to identify best source none with ideal relay. The simulation setup is done with a maximum of 250 nodes, 10 joule of initial energy for a transmission range of 100 m with depth threshold value of 60 m. Increased Throughput in DEAC protocol is identified from packets received at sink. This increase is achieved by alternative relay node. At initial working condition to operating stage, the energy consumption is gradually reduced, and worked on less energy utilization. The packet drop is less due to selection of better link quality which results increase in packet acceptance ratio highly. The DEAC network model comprises of sensor node and sink nodes. The sensor nodes are constrained with limited battery power and are positioned randomly while the sink node has no energy constraint and are deployed on the water surface. The data reliability and throughput is improved in DAEC protocol. The routing strategy used is cooperative routing to achieve better throughput. The dying of nodes are addressed at various depth thresholds.

Quality-of-Service Aware Evolutionary Routing Protocol

Quality-of-Service (QoS) Aware Evolutionary Routing Protocol the underwater sensors are deployed at different depth rate to attain cooperative sampling of 3D ocean Scenario. The 3D architecture is mapped to 2D and the following properties are taken into consideration to communicate with each other. The assumptions followed are sensor nodes are deployed randomly and have the same capabilities in terms of transmission range and initial energy. In this type of protocol the sensor node near to sea level can direly communicate with each other. The second assumptions made are each sensor node knows its own location by means of location service. Third every sensor node randomly moves only in horizontal direction. Forth acoustic channel is symmetric (the energy required to transmit the message from i^{th} node to j^{th} node is same as the message transmitted from j^{th} node to i^{th} node). Sensor nodes can adjust transmission power automatically between its high and low value. Carrier sense multiple mechanisms are assumed as the sink node is capable of receiving multiple packets at the same time. The energy consumption is better in case of Vector-Based Forwarding (VBF) when compared to DBR for data rounds between 1000 to 2000. The residual energy performance is better in DBR than VBF between the data rounds 2300 and 3150. QERP gives better performance than DBR and VBF as it keeps the sensor nodes alive in various data rounds. QERP relies better data transfer rate with even energy distribution and even data traffic load in the network.

RIAR

It is a Meddling Aware Consistent protocol. Void hole problem and channel interference problem are the two main constraints in UCS. This protocol comprises of network phase, data-forwarding phase, CF-updating and maintenance phase. In this each sensor node find its neighbor node within its transmission range and calculates the physical distance towards sink and hop-count sink. In data-forwarding phase the sender node select the next forwarder node based on CF. A CF keep informed and maintenance phase is sporadically performed to update each sensor node about its hops from the sink, physical distance from the sink and neighbor information. This protocol is analyzed both in sparse and dense environment. The reliability of sparse node region is improved and probability of collision in dense region is reduced by using reliable and interference aware routing protocol. [13] shows the performance of RIAR and Weighting Depth And Forwarding Area Division (WDFAD)-DBR, in which the data transmission packet ratio is better, energy efficiency rate, is improved; energy consumption is less with short E-ED when compared with WDFAD-DBR.

EEIRA

The EEIRA Protocol combines direct and relay forwarding mechanism to transmit the DPSN from source node to sink node. Direct transmission can also be done when the DPSN are not within the data transmission range of source node. If the data transmission happens directly from source to sink without relay node then the energy consumed by the system is more.

Sensor nodes are deployed randomly in 3D environment. The depth distances for different regions are shown in Table 1 [14]. All the nodes in the N/w are energy constrained except sink. Therefore the energy consumption by the system is reduced by increasing the number of relay nodes. As the relay nodes are increased more and number of DPSN can be transmitted with larger transmission efficiency, less E-ED and more data throughput and less energy consumption. Also the relay node checks with the sink node for its transmission range.

EECOR

From the local depth information, a forwarding relay set has been created by the Source node initially; further the Fuzzy function is used to select the best forwarding relay for transmission. This protocol sets a Holding Time to avoid packet collisions. The average Packet Delivery Ratio (PDR) of this protocol starts with a range of 0.26 (PDR) in 10 nodes to 0.92 (PDR) in 700 Nodes. This has been achieved by neglecting other relay nodes which are in the same region of depth, So the Packet Delivery Probability (PDP)

Table 1 Depth distances for different regions.

Region	Depth
Top region (Destination nodes)	0 <= D < 150
Mid region (Relay Node)	150 <= D < 350
Bottom region (Source Node)	350 <= D < 500

increasing. With less Energy this protocol delivers packets to source sink, for 100 nodes nearly 40 Joules, and for 700 nodes 270 Joules, which is very less consumption of energy by selecting a best forwarding relay using Fuzzy Sets. Packet Collision with retransmission is avoided by setting the holding time. This protocol concludes to select the best forward relay using fuzzy sets which leads more network lifetime. Energy Consumption problem is addressed in EECOR protocol. Opportunistic routing concept is utilized to overcome the energy consumption challenges of acoustic signal propagation and to increase the communication reliability. From [7] it is clearly understood that the energy consumption is less compared to other 4 protocols to deliver the same level of DPSN to surface sink. The energy consumption is less as the forwarding relay node set is selected based on the neighbor node fitness factor and also the holding time in forwarding relay node in relay set prevent packet collision and data retransmission. EECOR protocol gives better performance in terms of energy consumption and transmission efficiency.

2.1.4. Protocols addressing energy consumption

Depth And Reliability Aware Delay Sensitive

The opportunistic routing concept is modified in (DRADS) protocol. When the forwarder sends the data packet to the sink the depth of information is considered along with link-state information. This reduces the energy consumption and data throughput is increased. Due to Opportunistic routing the data load is high at low-depth nodes as they die soon and detoriate the entire performance of the system.

Enhanced Channel-Aware Routing Protocol

In this the DPSN are forwarded in a greedy hop-hop manner and the relay nodes are selected under steady network conditions. Energy Consumption and network lifetime is improved in E-CARP and E-ED is high due to waiting time. The routing strategy used is greedy hop packet forwarding strategy. This routing protocol considers the previously collected sensory data. Thereby the communication cost is reduced with increase in network capability. The E-CARP doesn't include DPSN and not beneficiary to the applications. This protocol fixes the low bandwidth, large propagation delay issues and enhance the approach to reduce the energy consumption and increase the network lifetime. The stability factor of the sensory data and variation factor β plays a vital role in improving the data transmission efficiency and reducing the energy consumption during the transfer of data packets.

Depth-Based Routing Aware Mac Protocol

In this protocol at low-depth nodes, the loads on DPSN are high and are prioritized to access the channel. To access the channel with greater preference at low-depth node the angle, depth and overhead of the neighbor node is considered. This consideration leads to improvement in energy consumption, data throughput and E-ED.

2.1.5. Protocols avoiding the void region

CARP

This protocol utilize the strategy of combining the hop count along with power control strategy to deliver data packets successfully, avoid void and shadow zones. Data transmission history introduces delay and the E-ED is larger.

EBPR

The Energy Balanced Pressure Routing (EBPR) use the feedback from sensor nodes for beacon signals to avoid void. Routing strategy utilize the residual energy in selecting the forwarder node. The lifetime of the network is improved but the performance is poor under sparse network.

LF-IEHM

The LF-IEHM for UWSN deploy sensor nodes randomly. Communication between the nodes can happen between acoustic waves and radio waves. But mostly radio waves are not used for nodal communication as it the radio waves are poorly affected by water. The LF-IEHM network model where the sink is connected at the top-mid surface. The Sink uses both acoustic waves and radio waves for communication purpose. Sink communicate with sensor nodes by an acoustic waves and with data-on-shore center by means of radio waves.

In this location free protocol, after the deployment of sensor nodes, every node broadcast a PING packet that contains its own pressure level and unique ID (UID). Every Sensor nodes has its own neighbor nodes and each neighbor node is characterized by its own pressure level and UID. On receiving the response from neighbor, the broadcaster node obtains information about the neighbor that contains pressure level and UID. Table is constructed between the broadcaster node and neighbor node pressure level and UID. When a PING packet is sent by the broadcaster node, it waits for the response from the neighbor node. If no response is received within the stipulated waiting time, once again the broadcaster node send HELLO packet. When the neighbor node Pressure level and UID matches with the sensor node Pressure level and UID then data transmission takes place from node to sink by an acoustic wave. The total energy consumption in case of LF-IEHM protocol is slightly more as the broadcaster node continuously sends HELLO packet till it receives an identical neighbor node with reference to pressure and UID. Though the energy Consumption is high the data transmission rate at the sink is high compared to the other two protocols (Novel Efficient Forwarding Protocol [NEFP], Energy Hole Repairing Depth- Based *Routing Protocol* [EHRDBR]) and data loss in the network and E-ED is reduced.

2.2. Localization Free Routing Protocol

The Table 2 summarizes the protocol to arrive the best choice for underwater applications where scalability is desired.

3. DETAILS OF SURVEY

3.1. Comparative statement of Protocol Grouping

The localization free protocols doesn't use 2D or 3D position coordinates of sensor node, instead it uses pressure sensor to measure the pressure of water on sensor nodes and in-turn the depth of the sensor nodes. The location free protocol is categorized as below. The Comparative statement is furnished in Table 3.

Table 2 Localization free protocol comparison.

Sl. No	Protocol	Routing Strategy	Issues addressed	Pros	Cons
1	LF-IEHM	Variable transmission range of sensor nodes and data packet holding time is combined to evade energy holes and interference.	Addressed energy hole formation and interference that portends reliable delivery of data packets.	High data throughput.	Consumption of energy is high.
2	RE-PBR	Random Topology/Grid Topology.	Communication Void in UWSN.	1. Every sensor node selects the forwarding node with higher residual energy and better link quality. 2. lLonger lifetime of the network and more stable with increase in network density.	The performance under sparse condition is compromised as beacon signals do not work effectively.
3	QERP	Divide the network into clusters and cluster head for data-forwarding.	Severe Channel Condition.	1. Better Data transfer rate. 2. Even energy distribution and data traffic in the network. Higher energy efficiency.	Overloading of cluster head happens and it dies fast as a result there is an occurrence of energy holes.
4	DUOR	Sensor nodes, hop count and depth are the essential conditions of candidate set. It's a receiver based scheme. Source node broadcast the DPSN embedding with surrounding region data.	Mobility of sensor nodes and scalability of underwater system. Communication void.	1. Less energy consumption to transfer the data. 2. Higher packet delivery ratio. 3. Lower energy consumption.	The lower priority node should suppress the data-forwarding transmission when over-hearing the higher priority transmission.
5	EnOR	EnOR utilizes the energy available during the progress of each neighbor node and its link reliability to its neighbor when establishing the prioritization procedure and candidate set	Immutable transmission priority level is addressed.	1. Balance in energy consumption. 2. Lifetime of sensor node is improved.	1. Communication Void Problem. 2. Short signal overload the network and causes higher energy consumption.
6	DRP	Employ the distance between the sender and the receiver and also the residual power for each node along the route. Beacon message is used to obtain the route information.	The transmission collision probability difference results with difference transmission distance are addressed.	1. Extends Network lifetime. 2. Increase in network throughput. 3. Decrease in E-ED.	Higher Energy Consumption.
7	EECOR	Opportunistic routing concept is utilized to forward the data packet to destination node.	Adverse channel condition.	1. Better Energy Consumption and transmission efficiency. 2. Increase communication reliability.	Communication among nodes in forward candidate adds delay.
8	RSS	RSS vector truth table is constructed based on the received signal strength. RSS vector truth table as base the sender node select the nearest neighbor node for next-hop	Energy Consumption.	1. Decreases propagation delay, and save energy consumption with better data transmission efficiency.	Inside the vector the data loading takes place at the nodes is high.

(*continued*)

Table 2 Localization free protocol comparison. *(Continued)*

Sl. No	Protocol	Routing Strategy	Issues addressed	Pros	Cons
9	BMOOR	Optimized opportunistic routing concept is utilized to forward the Data packet through multi-hop from down-stream node to up-stream node.	Adverse channel condition.	Delay minimized and maximized the data delivery ratio.	Multi-sink with suitable recovery mechanism has to be investigated.
10	HYDROCAST	Opportunistic routing concept is utilized based on pressure with dead & recovery method to ensure data packets sent to destination.	Balance in Energy Consumption	Improved Energy Efficiency	Under sparse condition the performance is compromised. Due to opportunistic routing the data load at low depth is high.
11	DEAC	Routing concept use cooperative communication to avoid data exploitation by channel.	Adverse channel condition.	Data throughput is high. Reliability is high	Energy Consumption is high due to cooperative routing.
12	DSRP	Routing concept is utilized to transmit the DPSN to surface sink based on position of nodes and velocity change.	Mobility in nodes	Data throughput is high.	Energy consumption and E-ED is high.
13	RIAR	Routing strategy uses the distance from surface sink, source node and other neighbor-hood nodes to select the forwarder.	Adverse channel effects.	Improved energy efficiency and high data reliability.	Sensor nodes closure to water surface dies early.
14	EEIRA	The lowest depth and the least number of neighbor-hood nodes to select the forwarder node.	Interference in data communication.	Energy efficiency.	The performance seems to be poor when neighbor nodes are not available at forwarder nodes @ low density networks.
15	EBECRP	Clusters and mobile-sink of two numbers are used to collect the data from nodes.	Balance in energy consumption	Energy balance and energy efficiency.	Data pack loss occurs due to the movement in cluster heads or death.
16	ODBR	Optimized routing strategy.	Uniform energy consumption.	Energy balance and energy efficiency.	Transmission loss is more for more rounds.
17	E-CARP	Hop-hop forwarder selected in greedy manner and is accomplished under steady network condition.	Energy consumption and network lifetime.	Higher energy efficiency.	E-ED is higher as the time for the channel condition to become stable is required before it selects the relay node.
18	WD-FAD	Forwarding nodes are selected based on weighting sum of depth difference of two hops (current depth and depth of next-hop is considered).	Probability of meeting void holes.	Reduced energy consumption. high delivery ratio	Average E-ED. Balance in energy consumption is a concern in selecting the next-hop forwarding node on the basics of node velocity.
19	DREE	Routing concept uses the physical distance to transfer the DPSN from source node to sink.	Link quality.	Reduced energy consumption and better delivery ratio.	Distance based protocol.
20	Co-UWSN	Cooperative routing concept is utilized to forward the DPSN using the nearby sensor nodes as relay nodes.	Adaptive mobilit	Better energy consumption, improved network lifetime and reduced E-ED.	Stability.

LF-IEHM, Localization-Free Interference and Energy Holes Minimization Routing; UWSN, Underwater Wireless Sensor Networks; QERP, Quality-Of-Service (Qos) Aware Evolutionary Routing Protocol; DUOR, Depth-Based Underwater Opportunistic Routing Protocol; EnOR, Energy Balancing Routing Protocol; E-ED, End-End Delay; EECOR, Energy Efficient Cooperative Opportunistic Routing; RSS, Received Signal Strength; BMOOR, Balanced Multi-Objective Optimized Opportunistic Routing; DEAC, Depth Threshold Protocol; DSRP, Delay-Sensitive Routing Protocol; DPSN, Data Packet Switched Network; RIAR, Reliable And Interference-Aware Routing Protocol; EEIRA, Energy Efficient, Interference And Route Aware; EBECRP, Energy Efficient And Balanced Energy Consumption Cluster Based Routing Protocol; ODBR, Optimized Depth Based Routing; E-CARP, Enhanced Channel-Aware Routing Protocol; WD-FAD, Weighting Depth And Forwarding Area Division; DREE, Distance Based Reliable And Energy Efficient; Co-UWSN, Cooperative Energy-Efficient Protocol For UWSN; RE-PBR, Reliable and Energy efficient Pressure-Based Routing Protocol.

Table 3 Comparative statement of protocol grouping.

Protocol Grouping	Protocol Strategy	Issue Addressed	Merits	De-merits
Protocols addressing node mobility	Routing strategy utilize the depth information of sensor nodes as forwarder selection parameter.	Node mobility.	Data throughput is high.	Non-utilization of residual energy and depth information. Network lifetime is reduced.
Protocol addressing energy-balancing	Forwarder node is selected at lowest depth and highest residual energy. Clusters and mobile-sink of two numbers are used to collect the data from nodes.	Immutable transmission priority level is addressed.	Balance in energy consumption. Lifetime of sensor node is improved.	Communication Void Problem. Short signal overload the network and causes higher energy consumption. Data pack loss occurs due to the movement in cluster heads or death.
Protocols extenuating channel conditions	Cooperative communication to avoid data exploitation by channel. Divide the network into clusters and cluster head for data-forwarding.	Severe and adverse channel condition.	Data throughput is high. Reliability is high. Even energy distribution and data traffic in the network. Higher energy efficiency.	Energy consumption is high due to cooperative routing. Cluster head overloads. Sensor nodes closure to water surface dies early.
Protocols addressing energy consumption	Opportunistic routing utilizes the depth information along with the link-state information. Greedy hop packet for forwarding strategy.	Energy consumption.	Energy efficiency is high.	Load on data at depth node is high. Larger propagation delay issues. E-ED is high.
Protocols avoiding the void region	Used the concept of combining hop count and power control strategy to deliver data packets. Also utilize residual energy to select forwarder node.	Communication Void, void-hole and channel interference.	Lifetime of the network is improved.	E-ED is high. Poor performance under Sparse network.

E-ED, End-End Delay.

1. Protocols addressing node mobility
2. Protocol addressing Energy Balancing
3. Protocols extenuating channel conditions
4. Protocols addressing Energy Consumption
5. Protocols avoiding the Void Region

3.2. Performance Analysis of Protocol Grouping

The performance analyses of various protocol grouping are given in following tables. The protocol addressing node mobility addressing data nodes are given Table 4 from [2] and [12], comparing the energy consumption, data throughput, E-ED and network lifetime. On comparing DBR and DSRP, DSRP protocol is chosen to implement the performance effect on number of nodes and node mobility in single source traffic applications.

Energy consumption is an important aspect in UCS. To attain better energy efficiency the transmission loss has to be minimum. The result in Table 5 and Table 6 [16] gives the comparative statement for total energy consumption and from that it is observed that the ODBR protocol is seems to be best for better energy balancing system.

The Table 7 gives detail analysis and comparison of NEFP, EHRDBR and LF-IEHM protocol with respect to energy consumption [1]. The total energy consumption in case of LF-IEHM protocol is slightly more as the broadcaster node continuously sends HELLO packet till it receives an identical neighbor node with reference to pressure and UID. Though the energy Consumption is high the data transmission rate at the sink is high compared to the other two protocols (NEFP, EHRDBR) and data loss in the network and E-ED is reduced.

4. CONCLUSION

A survey of state and art of localization free protocol for UCS is presented. Challenges associated with UWSN is analyzed, Considered and characterized. The protocols are grouped and categorized based on problem statement that addresses node mobility, energy balancing, avoiding Void Problem, energy consumption, mitigating the channel properties. In this paper various localization free protocol techniques were discussed to solve the issues faced in underwater sensor networking system.

Table 4 Protocols addressing node mobility (data nodes).

	DBR				DSRP		
	Grid Topology		Random Topology				
Data Nodes	Total Energy Consumption (Joules) in Grid Topology	Network LifeTime (Sec)	Total Energy Consumption (Joules) in Random Topology	Network LifeTime (Sec)	Total Energy Cconsumtion (J)	E-ED (ms)	Data Throughput (kB/s)
100	60	680	75	700	0.6×10^3	20	3
200	100	600	140	600	1.2×10^3	80	14.5
300	125	600	165	550	1.8×10^3	105	20.5
400	140	590	175	540	2.4×10^3	165	28.5

DBR, Depth-Based Routing; DSRP, Delay Sensitive Routing Protocol; ED, End-End Delay.

Table 5 Protocols addressing energy balancing.

	EBECRP			ODBR			EEDBR		
Rounds	No. of Packets Dropped	Energy Per Round	No. of Dead Nodes	No. of Packets Dropped	Transmission Loss	No. of Alive Nodes	No. of Packets Dropped	Energy Per Round	No. of Dead Nodes
200	0.5×10^4	700	0	1	35	60	0.4×10^4	220	95
400	1×10^4	400	0	0	30	50	1.2×10^4	80	160
600	1.5×10^4	120	60	1	29	25	1.8×10^4	20	175

EBECRP, Energy Efficient And Balanced Energy Consumption Cluster Based Routing Protocol; ODBR, Optimized Depth-Based Routing; EEDBR, Energy Efficient Depth-Based Routing Protocol.

Table 6 Protocol addressing energy consumption.

	ODBR			DBR		
Rounds	No. of Packets Dropped	Transmission Loss	Packets Received	No. of Packets Dropped	Transmission Loss	Packets Received
500	1	34	62	4	30	40
1000	7	33	36	20	0	5
1500	21	27	8	0	0	0

ODBR, Optimized Depth-Based Routing.

Table 7 Protocol addressing void region.

	CARP				EHRDBR				LF-IEHM			
Data Rounds	Total Energy Consumption (Joules)	Total No: of Packets Received @ the Sink	Total Packet Drop in the N/w	End – End Delay (S)	Total Energy Consumption (Joules)	Total No: of Packets Received @ the Sink	Total Packet Drop in the N/w	End – End Delay (S)	Total Energy Consumption (Joules)	Total No: of Packets Received @ the Sink	Total Packet Drop in the N/w	End – End Delay (S)
25	5500	3400	3400	1200	5000	3200	2000	1490	6000	4200	1000	1250
50	20000	4000	4800	1900	9000	5400	3900	2600	10000	7800	1800	2250
100	18000	4000	9000	2600	13000	5400	7200	3400	14000	9200	3000	3050
150	41000	4000	10200	2750	14000	5400	8200	3600	14000	9200	3000	3050

CARP, Channel-Aware Routing Protocol; EHRDBR, Energy Hole Repairing Depth-Based Routing Protocol; LF-IEHM, Localization Free Interference and Energy Holes Minimization Routing.

The main objective of the paper is to provide different solutions to the challenges faced in underwater communication network and gives direction for further research and improvements in terms of energy consumption, utilization, Traffic Security, Link reliability, Integrity, Battery lifetime and better energy efficiency. In Future the experimental analysis and investigation for noise attenuation can be developed to reproduce the physiognomies of UWSN. The Sensor node localization is a challenging task as the node moves and changes its position frequently with reference to water current direction. The movement of the node information has to be updated continuously as this adds delay and consumes more energy on information exchange. The medium in UCS is unpredictable and hence the design of protocol should focus more on data transmission reliability from underwater node to sink node. The disparity of the acoustic speed with reference to depth, temperature and salinity of the water causes the acoustic waves to travel on curved paths and forms the region where the sensor nodes can't communicate with other nodes in their locality. The analysis and design of routing protocols should face this challenging issue. Every protocol is described in terms of routing strategy, node mobility, energy consumption, E-ED and makes us to decide better protocol upon our applications. The cons prescribed lead to the design of most efficient and effective Protocol.

CONFLICT OF INTEREST

The Authors declare no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the publication of this article with regard to the review and editing, validation of the numerical model, study analysis and writing.

ACKNOWLEDGMENT

This research was a part of the project titled "Development of Ocean Acoustic Echo Sounders and Hydro – Physical Properties Monitoring Systems", which is funded by the Ministry of Oceans and Fisheries, Korea.

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