A SURVEY OF ROUTING PROTOCOLS FOR UNDERWATER WIRELESS SENSOR NETWORKS

[1]Anbuselvi A, [2]T. Ramesh,

,[1]Research Scholar, [2]Associate Professor
[1]Department of Information Technology, [2]Department of Information Technology
harathiar University, Coimbatore, India.

Abstract : The Underwater Wireless Sensor Networks faces a number of challenges induced by the nature of the underwater environment and its influence on the physical media. Routing protocols in Underwater wireless sensor networks have set of rules that are used for the purpose of routing to find a particular node. Each routing protocols have unique quality of the function and route the data from source to destination node. They perform in different roles in UWSNs. This paper surveys a number of the recent routing protocols for UWSNs. Specifically, the idea of each protocol is presented as well as its advantages and disadvantages. Above all this paper briefly explains all the routing protocols and their duty in UWSNs.

Index Terms - Wireless sensor networks, Router, Sensor nodes, Underwater wireless sensor networks, Routing protocols, energy efficient.

I. INTRODUCTION

Water covers over 70% surface of the earth. Communication under the water region It is very difficult due to its nature. The successful deployment of wireless sensor networks in underwater make it possible. Communication between sensors and base station or between the nodes is different from the terrestrial scenario. A UWSN is comprised of underwater sensor nodes, which are made with sensing, processing, storing units. Underwater wireless sensor communication capabilities that act collaboratively to monitor underwater regions. Communication using electromagnetic waves face many difficulties because of high attenuation and absorption effect of water. Acoustic communication is the best mode of communication. The use of the underwater acoustic mode allows these devices to wirelessly communicate with each other to perform real-time underwater monitoring, online system reconfiguration, and detection and report of operational failures and malfunctioning devices.

1.1 WIRELESS SENSOR NETWORK (WSN) IN UNDERWATER COMMUNICATION

The network that possess spatially distributed autonomous sensors to watch physical or environmental conditions like sound, vibration, pressure, temperature, motion or pollutants in conjunction with cooperatively passing data via network to a main location is termed as Wireless Sensor Networks (WSN)[1]. the massive number of sensing devices equipped with limited computing and radio communication capabilities are contained in sensor networks. The sensors in some network configuration works even after not attending and transmit their observation values to some center and that they are called as sink nodes that function interface . Sensors that are distant from the sink deliver their data with the assistance of intermediate nodes as relays. The sensors are often both a knowledge source and a knowledge router.[2].

Sensor nodes sense the environment and generate the data depending upon the data. The sensor node sends the data to the base station through the intermediate nodes.. The data should reach the base station through a reliable path. The reliable path reduces the retransmission of data, which can decrease link and energy reduced. So, the sensor node requires appropriate energy and reliable path for data transmission. Underwater Wireless Communications (UWCs) are implemented using communication systems supported acous-tic waves, frequency (RF) waves, and optical waves. Underwater acoustic wireless communications (UAWCs) are one among the foremost used UWC technologies because it provides communication over very long distances.

In 1995, an UAWC system was proposed in [23] with the info rate of 40 kbps. In1996, an 8 kbps UAWC system was developed for a depth of 20 m and horizontal distance of 13 km [2]. In 2005, a more high-speed UAWC system was proposed by H. Ochi, Y. Watanabe, and T. Shimura during which records a knowledge in “Basic Study of Underwater Acoustic Communication Using 32-Quadrature AM ,” Jun. 2005 [13] rate of 125 kbps using 32 quadrature AM technique (QAM) with symbol error rate of 10^{-4}.Furthermore, a 60 kbps UAWC system was demonstrated by H. C. Song and W. S. Hodgkiss using 32 QAM in “Efficient use of bandwidth for underwater acoustic communication,” 2013[14] which may support communication over depth of 100 m and horizontal distance of three km. However, acoustic waves still have more disadvantages including scattering, high delay thanks to the low propagation speeds, high attenuation, low bandwidth, and bad impacts on the underwater mammals and fishes. where the R. K. Moore have discussed in “Radio communication within the sea,” IEEE Spectrum, vol. 4, no. 11, pp. 42–51, Nov. 1967[21] different modulation schemes, channel models, link management, and coding techniques along side the possible practical implementations of UOWC systems.

II. RESEARCH ON ROUTING PROTOCOLS IN UNDERWATER SENSOR NETWORKS (UWSNS)

The medium characteristics of underwater communication are long propagation delay of the acoustic signal and extreme volatility of the link quality, there are many issues within the design of routing protocols for underwater acoustic sensor networks.

So as to affect this unreliable and unstable nature of the acoustic medium, researchers in several ideas have projected multi-hop data delivery routing protocols between the sources and destination. These routing protocols are mostly enthusiastic in to the structure. The underlying acoustic network making them unsuitable for pure adhoc networks. Hence limited in their applications.

There are many sorts of routing protocols proactive, reactive and geographical. Proactive - protocols effect an outsized overhead to make the routes, here periodically or whenever when the topology modified. Reactive - protocols cause large delays and need the source to initiate flooding of control packets to make the paths and are more appropriate for the dynamic networks. This makes two sorts of routing protocols unsuitable for UWSNs. Geographical routing relies on geographic position information; hence the info packets are sent using its geographic location of the destination.

III. ROUTING PROTOCOLS FOR UNDERWATER SENSOR NETWORK

(i).Reliable and energy efficient routing protocol [REEP][20] This routing protocol uses the ToA mechanism for calculating the distance between source and sink node. The network development and data forwarding phases focuses the operation of the REEP. In REEP the forwarder node selection is based on location information and residual energy. For data forwarding the three formats are uses, one is hello packet format, second is reply format and third is data packet format. REEP is only based on the use of vertical modem, whereas, if network become sparse then forwarder node will drop the packets and will die earlier.

(ii). Energy Efficient Clustered-Based Routing Protocol [CBE2R][4] protocol is proposed for control the node mobility and prolong the battery power of the nodes. CBE2R dividing the water depth into seven numbers of layers from top to seabed for controls the node mobility and prolongs the battery power of nodes. In CBE2R the battery power through powerful static courier nodes which are deployed from sea surface to seabed on different layers. Clustered-based routing protocols with highest weighted value for data forwarding is based on seabed to under layer courier nodes through ordinary nodes. The courier nodes in bottom layer that gather the data information from ordinary nodes and forwards to surface sink nodes by maximum energy levels (p1, p2, …., pn-1) through courier nodes or head nodes which are deployed in different layers.

Clustered Based Energy Efficient Routing [CBE2R] cannot perform well when network becomes sparse. [EMGGR][9] that due to the water pressure the 3D grid formation mechanism cannot perform well. The multipath route development mechanism has been adapted in DRP for packets forwarding. It is observed that DRP cannot control its distance due to node mobility and cannot show its well performance. REEP is only based on the use of vertical modem, whereas, if network become sparse then forwarder node will drop the packets and will die earlier.

Nonetheless, since more redundant information is required by Tornado Codes, this is not a very helpful method for UWSNs When an event occurred, the Dynamic Clustering was initiated by Bharamagoudraa, M. R., Manvi, S. S., and Gonen, B. [2017]. Rathna, R., and Siva Subramanian, A. [2011][[7] described in TDMA based low energy consuming MAC protocol for wireless sensor networks in environmental monitoring applications[8].

A TDMA based Low Energy consuming MAC Protocol for Wireless Sensor Networks was suggested. The sleep/wake up scheduling, when applied over the radios, can reduce the overall energy consumption of the Wireless Sensor Network minimally. Gomathi, R. M., and Martin Leo Manickam, J. [2015][10] state that Energy preserved Mobicast Routing Protocol by creating static node in every (zone of reference) ZOR region to minimize energy[13].Gomathi, R. M., and Martin Leo Manickam, J. [2016][11] described about different routing protocols of underwater sensor network are analyzed[14].

In cluster based routing, the network is divided into a number of clusters/cells based on the geographical location of the nodes. Once the network is divided into clusters, the cluster head (i.e., OAP/OBS) is selected for each cluster by using any cluster head selection strategy. The cluster head is employed as a gateway to speak between the clusters and to the sink node.

A Distributed Clustering Based Protocol was proposed by K. R.Anupama, A.Sasidharan, and S.Vadlamani. [2008][15] where the communication between the cluster head and the sensor node was single hop. M. C. Domingo and R. Prior, are proved that Location unaware cluster based multi hop routing protocol where the sensor nodes do not know their location and location of the cluster head[21]. The interested readers D.N.Sandeep and V.Kumar. [2017][8] are referred in "Review on Clustering, Coverage and Connectivity in Underwater Wireless Sensor Networks: A Communication Techniques Perspective" to a number of cluster based routing protocols are highlighted for underwater wireless sensor networks[10].

(iii). An Energy-Efficient Multilevel Adaptive Clustering Routing Algorithm [ACUN][23] Routing algorithm is implemented for improve the energy efficiency. ACUN considers the residual energy of the cluster-head to decide the size of the contest radius. ACUN looks the larger energy during selection of the cluster-head node to prolong the battery power of the node. ACUN balance the energy level of the nodes through single or multi-hop route selection techniques. The ACUN that the cluster-head selection through radius with layered formation mechanism is the difficult due to distance measurement, because this kind of mechanism is unable to maintain the overall network performance. It is also observed that when network becomes sparse the cluster-head node will drop the packets continuously and will die earlier.

ii. Energy-Efficient Depth-based Routing Protocol [EEDBR][22] when forwarding a knowledge packet from a sensor node to sink, the packet is transfer by the actual nodes consistent with the depth and energy. Each nodes sends the packet with neighbor's IDs. Which having smaller depths than the sender. Hence particular nodes are eligible to forward the packet. EEDBR performs energy balancing by utilizing the residual energy information by the sensor nodes. The sensor nodes hold the packet for a specific time before forwarding. The time which hold the nodes is predicated on the energy of the sensor nodes. A node having high residual energy has short holding time compared to the node having low energy. Hence, the high energy node forwards the packet and therefore the low energy nodes repress their transmissions upon overhearing the transmission of an equivalent packet. Through this manner , the balancing of the energy consumption is performed thanks to the energy balancing, the sensor nodes consume their energy parallely and none of the sensor node's battery are going to be exhausted before others.

iii. Energy-Aware and Void-Avoidable Routing Protocol [EAVARP][25] that the complex mechanism for shell formation through The Opportunistic Directional Forwarding Strategy (ODFS) is mentioned, which only works in the limited area, even authors have not mentioned the performance parameters for dense or sparse area networks. The low weighted distance calculation mechanism is used to develop the route between low layer cluster-head node (courier node) to seabed source node for developing the stable route for packets forwarding, when cluster-head node will collect the packets then this node will forward the packets to the sink nodes which are deployed at water surface by using the maximum power levels through other layered courier nodes.

B. LOCATION BASED ROUTING PROTOCOL

Energy –Efficient Multipath Grid- Based Geographic Routing [EMGGR][9] This routing protocols form the 3D grids in underwater environment to control the underwater in 3D environment. In grids the multipath route development mechanism is adapted to forward packets from source to sink node. In grid cells the xyz addressing mechanism is used and every node is comprises the xyz addressing mechanism and are well aware about its location. The data is forwarded through virtual cell gateway from source to sink. It is observed from EMGGR that due to the water pressure the 3D grid formation mechanism cannot perform well.

A location-based routing protocol was introduced by K. R. Anupama, A.Sasidharan, and S.Vadlamani, in "A location-based clustering algorithm for data gathering in 3D underwater wireless sensor networks," [2008][15] in which the network into clusters and the data from the nodes are gathered by the cluster heads.

C. FLOODING BASED ROUTING PROTOCOLS

Diagonal and Vertical Routing [DVRP]: DVRP[16] uses broadcast routing mechanism. Zone angle towards the surface sink is employed to scale back the printed overhead. Low energy consumption is attained to increase the life time of the network [15]. Flooding is confined by selecting the route with the vertical direction and lowest angle towards the sink.

In Shortest Path Routing Protocol Based on the Vertical Angle for Underwater Acoustic Networks [SPRVA][17] the forwarding node determines the best next-hop according to main priority [4]. When the most priorities of candidate nodes are an equivalent, the choice priority is employed. The core priority is mentioned by the residual energy and angle between propagation direction and depth direction. Therefore the alternative priority is indicated by the link quality. SPRVA selects the node along the depth direction with more residual energy and better link quality because the best next-hop. Meiju Li et al show that SPRVA protocol decreases significantly energy consumption and end-to-end delay on the premise of ensuring delivery rate.

D. DISTANCE BASED ROUTING PROTOCOLS

Ahmed M. in "Distance Calculation Energy Efficient Routing Protocol for Underwater Wireless Sensor Network" [DCE2R][3] for Underwater Wireless Sensor Network, which develops the efficient route through Distance Calculate Formula (DCF) and prolong the battery power of the nodes.

IV. OTHER RESEARCH WORK DONE IN UNDERWATER COMMUNICATION.

Al-Shamma'a, A. Shaw, and S. Saman[5] are described due to the communication range limitations of UOWCs, relay-assisted UOWC is a key enabler technique to realize UOWNs by expanding coverage area, extending the communication range, enhancing energy efficiency, providing cooperative diversity, and improving the end-to-end system performance. Routing holds a significant place in order to keep the UOWNs connected by discovering and maintaining the transmission routes. A number of routing protocols for underwater acoustic wireless networks have been highlighted by A. Shaw, A. I. Al-Shamma'a, S. R. Wylie, and D. Toal, C. Uribe and W. Grote, [2009][8] some of which can be well adapted for UOWNs.

Abdul Wahid Sungwon Lee Dongkyun Kim[3] are state that in Reliable Energy-Efficient Routing Protocol supported Physical distance and Residual energy [REERP2R]. The main idea behind REERP2R is to develop physical distance as a routing metric and to balance energy use among sensors.

Gomathi, R.M, J. Martin Leo Manickam [9] propose one new multi-layered routing protocol [MRP] that can be used in discovery of the professional path and it also enhances the overall implementation of the end-to-end delay ration, effective consumption of energy, and network lifetime.

Resilient Routing Algorithm [RRA] [21], and so on provide agreeable energy efficiency, reliability, less congestion, interference, and short end-to-end delays associated with maintaining further routes. Hence, for avoiding repetitive transmission, there is a need for efficient solutions. Additionally, the changing grid configuration also is being totally ignored, which will lead to connectivity loss in the sparse networks. A given effective routine system toward re-clustering will be able to bring down the expenses and this region must be worked more for avoiding connectivity loss caused by changing grid configuration.

Guo, Z., Colombo, G., and Wang, B et al. [2008][12] state that the name adaptive routing is one localization-oriented scheme proves effective in the case of static networks. Packet privilege-oriented network resource allotment is the key idea behind this particular routing scheme. Therefore, it will be possible to deliver a vital packet reliably and with shortest end-to-end delay when compared with a normal packet. Still, this system is unable to support a network architecture that is dynamically reconfigurable. More recently, a work suggested grid-layer protocols that are particularly designed in connection with sub aquatic acoustic networks.

In routing protocol which establishes autonomously the sub aquatic grid topology is suggested. It controls grid resources and develops flows of network that rely on some centralized grid manager which runs on one surface position. Even though this idea seems promising, the functioning of this suggested system has not thoroughly been examined. For providing maximum reliability through Tornado Codes usage, Segmented Data Reliable Transport [SDRT] has been developed.

Ahmed M. [2019] Where Multipath Multi-layer Data Forwarding Routing [M2DFR][18] is designed to extract the information from the bottom of the sea with its applications like: gold, oil/gas and minerals. The improved performance of M2DFR is measured with CBE2R and EMGGR.[5]. In Distance Calculation Energy Efficient Routing Protocol for Underwater Wireless Sensor Network his research article controls the node mobility in underwater environment through maintaining link between nodes and prolongs the battery power of the nodes through Cluster-based Multipath Shortest-distance Energy Efficient Routing [CMSE2R][19].

One of the side effects of the low propagation speed of acoustic waves is that routing protocols of terrestrial wireless networks aren't applicable. To concentrate on this problem, routing strategies paying attention on different aspects are proposed like location free, location based, cluster based, energy efficient, etc. These mechanisms usually require measuring additional parameters, like the angle of arrival of the signal or the depth of the node, which makes them less efficient in terms of energy conservation. In Self-Organized Fast Routing Protocol for Radial Underwater Networks propose a cross-layer proactive routing initialization mechanism that does not require additional measurements and, at the same time, is energy efficient. The algorithm is meant to recreate a radial topology with a gateway node, such packets always use the shortest possible path from source to sink, thus minimizing consumed energy.

V. Conclusion

This paper describes the major task routing protocols for underwater sensor networks. This paper explained the methods implementation of protocols, advantages and limitations of each protocol.

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