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Clustering-based Energy Efficient Multipath Adaptive Routing Protocols for Underwater Wireless Sensor Networks

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Abstract: In an underwater wireless sensor network (UWSN), research challenges occur in the availability of new connectivity protocols, sensors, and utilization of energy. One of the issues is to enhance the lifespan of the network without increasing the supply, cost, and level of resources. This paper proposes a conceptual routing protocol for UWSN, known as Energy-Efficient Multipath Adaptive Routing (E^2MAR) protocols, which is primarily intended for long-term control with greater energy efficiency and transmission rate. Key development conditions were set by the E2MR and forward nodes are chosen based on the performance index. Different tests are carried out by evaluating E2MR in terms of the number of live nodes, end-to-end latency, packet delivery rate, and maximum energy usage efficiently compared to some other Routing protocols. The lifespan of the network has also been greatly enhanced.

Keywords: Underwater Wireless Sensor Networks (UWSN); Energy-Efficient Multipath Adaptive Routing (E^2MAR) protocols

I. INTRODUCTION

As a significant contributor to cable-based underwater implementations, Underwater Wireless Sensor Networks (UWSNs) [1] also received tremendous coverage. Although even that is generally very high, and thus mostly used by the main telecommunications sector, UWSNs are exploiting the more than high-quality service and growing efficiency of wireless underwater networking systems, varying from underwater to optic. Many frameworks, such as marine surveillance, port surveillance and defense, aquatic biodiversity, and marine archaeologists exploration and safety, among others [2], are all conceptually similar to the emerging design and analysis systems and UWSN parameters detector detects broad sectors of the underwater world [3]. It's still a new approach to implement effective and efficient technologies for multi-hop wireless underwater networking since technologies for wireless networking could be modified to operate underwater. The major reason is the very existence of the predominant underwater medium, such as the acoustic network, that, with several abnormalities, is affected by difficulties in transmission, poor bandwidth, extremely rapid dynamics, sluggish signal attenuation, and adaptive ties.

For example, in specific UWSN implementations, it is normal to note that, network entities can not be able to interact at all, regardless of the transmitting capacity of the system and its proximity, or the channel is asymmetrical. What makes things much more difficult is that these situations shift rapidly. Since these, developing underwater networks has involved methods that are somewhat specific from those used effectively for marine telecommunications. UWSN networking protocols [4] have so far indicated an effort to resolve these different behaviors of underwater communications. They perform better, therefore, to effectively fix ever-changing network requirements, like varying traffic and more evidently, the efficiency of the links and general environmental conditions [5]. The Underwater Wireless Sensor Network (UWSN) is a modern platform that enables highly successful and challenging technologies for underwater exploration in a wide variety of fields, including military protection, crisis, and industry worldwide. Intelligent and automated vehicles fitted with sensors are primarily developed for underwater monitoring [6].

For underwater environmental resource exploration, autonomous mobile vehicles were included. Automated vehicles built with sensors detect and transmit data directly to sinks. The sinks transfer data for analysis of the base station; the transmitter analyses the information and requires the relevant action [7]. They should not be used in submarine connectivity, since WSN is dependent on electromagnetic fields, that is why underwater sensor networks depend on cellular networks waves [8]. Here as sensor nodes transmit data to sink, the sinks, via electromagnetic radiation, forwards sensory details to other sinks [9].

In certain ways, UWSN varies from standard wireless networking. Requirements such as high delays in transmission or lower throughput are not typically seen in terrestrial networks, but in UWSN [10] they commonly have these challenges. In underwater communications, there are many challenges, like deep seawater, significant priority, diffuses impact, electromagnetic and perceptual patterns that do not function well enough in the underwater environment. To resolve the above concerns, findings suggest acoustic energy rather than radio signals for underwater data communication, and this increased the rate of data transfer [11]. Furthermore, a significant challenge in wireless communications is the limited frequency. So that's why, due to its energy utilization and edge latency, the sensor nodes of satellite systems are not appropriate for wireless communications. The configuration doesn't often remain the same even in underwater networks, since sensor networks are complex due to high-temperature flow. TCP/IP scheduling algorithms, packet loss networks, ad-hoc cellular nodes, ad-hoc vehicular networks [12], and WSNs can indeed be extended specifically to the underwater networks. Underwater networks could never be frequently attributed to network topologies that are found on other networks. For underwater sensor networks, several protocols are being suggested to date. These are specifically classified into two groups of protocols that are location-based and free of localization. No specific geographical or network data is obtained by considering the influence networks. These parameters are mainly found in underwater networks [7].

The main objective of the proposed algorithms, such as the protocols for clustering [13] based energy-efficient multipath adaptive routing (E^2MAR), is to prevent flooding-type routing and maximize the energy efficiency of each node. A few of the primary goals of this work can be summarized.

- **Energy efficiency:** E^2MR will minimize energy utilization, as should be shown in this article's subcellular localization.

- **Prevention of many iterations of messages:** E^2MR prevents all those routing protocols, that contribute to a huge variety of network messages, which increases the existence of the network. Including both the perception layer and sinks, the algorithm prevents lots of copies.

- **Prevent flooding:** E^2MR prevents flooding techniques in which the sent packet is forwarded to all nodes in the network by one node.

- **Packet-holding cycle:** E^2MR increases the time interval of packets, although energy consumption depends on the delay period. The maintaining cycle is improved by this algorithm.

- **Clustering:** Such as regional levels, heterogeneous clusters of nodes are developed based on residual higher frequencies. And use a probability dependent process, the cluster head is chosen.

Essential components of clustering are clustering, cluster head, and clustering process [14]. Clustering is performed with the help of cluster score, intra-cluster connectivity, inter-cluster connectivity, and hierarchical clustering. CH is the supervisor of this phenomenon, i.e., via some form of correspondence, gathering data from cluster head, aggregating data, and process efficiency to the access point. Our proposed system highly depends on enhancing energy reliability in UWSN, i.e. the node can continue to exist for a significant period, resulting in an improvement in network life. The communication system from node to sink occurs as a multi-hop communication in this process. Rather than the global level, multi-dimensional clusters of nodes are generated based on the remaining higher frequencies. Using a probabilities dependent process, the cluster head is configured. The remainder of the paper is structured as follows. For underwater wireless sensor networks, the design was described in Section II. Section III summarizes state-of-the-art routing. In Section IV, E^2MAR outlines the network situation, packet handling functions, and the routing paradigm based on clustering that determines interface functions. Section V shows simulation results. The article has been concluded in Section VI, detailing alternative future paths.

II. UWSN's ARCHITECTURE

The architecture of UWSN has been discussed in this section. Figure 1 illustrates the overall UWSN structure. The UWSN design typically comprises 5 separate elements, namely the data sensing module, the energy control module, the processing module, the data communication module, and the distance analysis module [15].

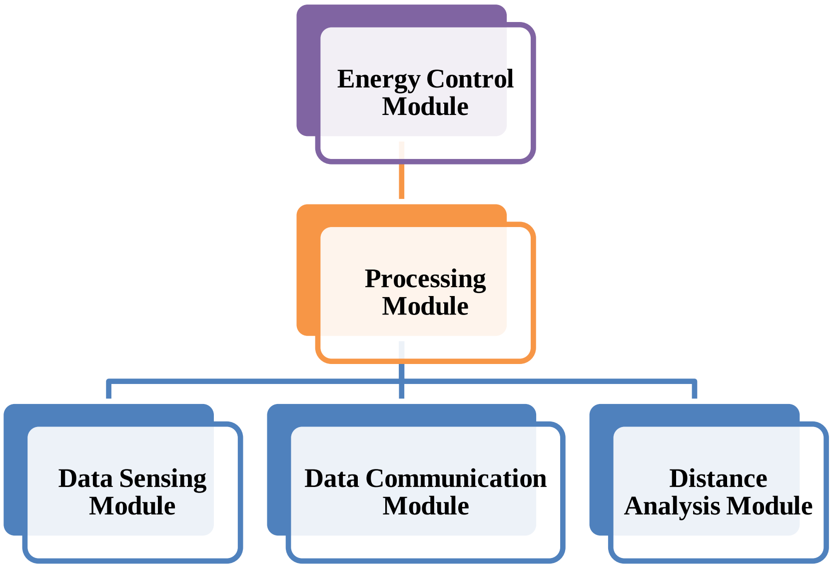

Figure 1. UWSN's Architecture

A. Data Sensing Module: The Data Sensor Module is capable of sensing some kind of UWSN data. For varying objectives, different types of sensor nodes (used for floods, underwater tools, and motion, etc.) are often used. In specific, apart from nodes in safe mode, the data sensor module senses data.

B. Processing Module: A few of UWSN's several significant measures are the processing unit. Some kind of processing is sufficient for it.

C. Data Communication Module: The data communication module is responsible for exchanging data between separate sensor nodes. It transfers information to the base station nodes from the sensing nodes and shares data between the sink layer and the network layer as well.

D. Distance Analysis Module: For calculating the depth of each node, the distance analyzing module is used. It plays a significant part since the node's location layer is quite critical in UWSN for routing. The location layer here corresponds to the depth of the water where a node is situated.

E. Energy Control Module: The UWSN is battery-operated, and it is almost difficult to maintain the battery. Thus, UWSN's performance relies on energy supply. The node would be switched down as a result of energy depletion, and this affects the network operation. Two functions are the responsibility of the energy control network, which controls the remaining energy of the nodes as well as maintains the node's utilization in runtime.

III. RELATED WORKS

Most studies have been performed over the past decade and some findings have been obtained in UWSN's to minimize energy usage. The author suggested a multimedia, cross-layer protocol by Khalid et al.[16]. The structure of the framework is as follows: (a) the analysis of the relationship of the basic features of the underwater wireless network, like the verification of forwarding errors, synchronization, controlling of network connectivity and routing; (b) The sensor networks will effectively share the bandwidth utilization depending on the configuration of a distributed cross-layer communication process. The protocol supports, by test findings, the increase of energy consumption and higher bandwidth.

Khalid et al.[17] suggested an automatic hierarchical routing protocol named E-PULRP for energy optimization - based route. The EPULRP comprises of a structured and connectivity level that uses a collection of the node as the central and other nodes placed on concentric rings, suggesting a complex architecture. The performance rate of nodes transmitting data and preventing node efficiency losses is increased by evaluating the distance of every layer and node energy losses. An alternative energy-optimized sensor network protocol communicates data to the sink node in the communication process. A comparison research trial with other algorithms shows the integrity of the energy-efficient technique E-PULRP.

A network of fading channel underwater acoustic communication de-multiplexing asymmetric communication protocol named the AMDC was suggested by Carlson et al. The protocol gets hold of the irregular distribution of underwater interference and the specific noise-attenuated aquatic transmission environment [18]. To increase the network energy quality and stability of data transmission, the underwater wireless domain is broken to create a tree-based multi-path communication protocol. Routing protocols are being recommended over a period for UWSNs. The most recent alternatives are [19], [1]. The user is directed to studies on the specific issue for information on both of these guidelines, and some more, including some by Li et al.[20] and more currently by Khan et al.[21]. Among the several approaches, the Channel-aware Routing Protocol (CARP) is one which holds out in addition to the overall great achievements, using interface relevant data to successfully execute data to the sink [19]. Based on their connection efficiency, hop count, and spectral efficiency, nodes are chosen as transmitters. CARP uses the RTS/CTS channel selection framework for channel access and packet relay collection. For this purpose, it generates significant latency and be stable, and minimizing packet losses. In high-traffic systems, nodes also attempt to achieve user privileges to the channel, resulting in a lower packet distribution rate.

Supervised learning is being used widely in multi-hop wireless network mapping, namely wireless ad-hoc networks, wireless sensor and cognitive radio networks, and more commonly in UWSN routing [22]. The value of learning-based routing benefits the online concept of efficient scheduling strategies, thereby maintaining and preserving the optimized path effectiveness in a challenging environment [23]. Learning algorithms are also useful for distributed applications and it is possible to make their transmission specifications comparatively low. For the constantly changing and resource-constrained UWSN setting, all of those are important and also attractive characteristics. Systems including those discussed in [22] for underwater networks involve particular situations that are not identical to the efficient risk management in this.

In sensor nodes, low consumption of data is needed. For wireless networks, the implementation of a routing process to enhance rapid and effective consolidation of data is often necessary. There are various routing protocols in UWSN, such as vector-based, Autonomous Underwater Vehicle, parameters dependent on depth, and cluster [24]. The author approaches a cross-layer in [25] where the data packet is transmitted through various channel power levels. This delay in transitioning is applied to this and a significant volume of energy is absorbed. OEB, incorporating both multi-hop and direct transmission, is described in [26]. The protocol takes the location of nodes and numerous data distributions via cables and geographical signals. Any such solution was enhanced, which requires GPS-free and hence minimizes the constructive networking interchange. In EBC, that is, the energy-balanced chain framework enhances the lifespan of the network. In [27], the authors state that a decrease in the rate of packet transfers and collisions between them is accomplished, which increases the rate of network portage and energy consumption. The protocol in [28] uses numerous sink node hops-up transfer techniques and asserts the cost-effectiveness of securing node depth or location.

Multi-hop and simple connection methods are merged in the protocol [29] which \ refers to the unorganized system. Because each node detects any benefit and transmits it to neighboring nodes, the difficulty occurs out to be a sudden reduction in energy of nodes that are next to sink. Paper [30] presents descriptions of the integrated view of the above-mentioned paper in which nodes have been randomly deployed and energy ratings have been preserved. But each variant also has drawbacks that have been submitted and evaluated correspondingly by various scholars. A clustering framework in hierarchical Unicode characters, such as LEACH [31], are some of the commonly distributed sensor networks. There has been a potential in the above article to better analyzing and working through all these underwater concepts by adding the aggregated network architecture involving clustering frequency equation using threshold and also transferring data between cluster heads with the hop by hop aggregation, which is described the sequential manner in our next section. Our proposed methodology is designed to keep the node alive to keep energy wild and to ensure the right transmission flow that correlates to enhancing the lives of the network.

IV. PROPOSED WORK

The proposed routing methodology for UWSN is discussed briefly in this article. The system architecture of the wireless underwater sensor node consists of the following components, namely the Energy control module, the data sensing module, the distance analyzing module, the data communication module, and the central processing module [32]. The processor module is appropriate for data processing of all types, whereas the energy management module is responsible for collecting the node's energy consumption. For sensing data, the data sensing devices are used to include this related data to the node ahead. Also with the node itself in an idle state, the data sensing device is only in an active state. The communication module is responsible for proper data communication, while the distance analyzing module is used when placed in the ocean to determine the depth of water.

The proposed approach would be effective in preventing data flooding phenomena and multiple copies from being made. It would be able to make sense of the layout of the underwater sensor network with many sinks. Multiple sinks fitted with both acoustic and radio-frequency handsets would provide this type of network. At the water surface, such sinks are configured. In the required underwater environment, static sensor networks are implemented. These nodes are responsible for gathering data and transferring it if several, two sinks in multi-hop mode or to dispatcher nodes. Frequent powers are given to dispatcher modules and they are only able to achieve data from static sinks and forward it to sink. A sink may interact effectively via radio stations with some other sink. This statement may be supported by the finding which noise responders in water nearly at the velocity of approximately 1.5 * 10^2 m/s, several magnitudes smaller than that of radio waves are generated in space at a rate of 310^8 m/s. Users also presumed in our case that a packet achieves its destination as early as it is efficiently sent to either of the sinks.

The highest-energy cluster head sends data to the sink, and several cluster heads transmit data through the hop process to that cluster head. In a system, this same protocol is applied all over the network phase. The below mentioned probabilistic formulae would be performed at scales that have been used to establish the clusters and cluster head development. After that, the various clustering phases will be determined by a significant feature, i.e. mapping function. Enhancements to our configuration are dependent on a clustering method that involves the common interaction between sensors to construct a cluster network. The clustering algorithm provides a multi-phase cluster creation & a cluster head selection, data configuration, data collection, and transport [33]. The system has three phases in the proposed work in which nodes are separated depending on their energies. Advanced Phase: Nodes have optimum energy beneath this limit. Common Phase: Nodes provide low power under this phase. Integrated Phase: Nodes between the advanced and regular phase has energy under its phase. The probability of the coefficients of these three phases are related to as the following equations (1), (2), (3):

$$P_{com} = \frac{P_{apr}}{1+i*\beta+j*\theta} \tag{1}$$

$$P_{med} = \frac{P_{apr}(1+\theta)}{1+i*\beta+j*\theta} \tag{2}$$

$$P_{enc} = \frac{P_{apr}(1+\beta)}{1+i*\beta+j*\theta} \tag{3}$$

Where, P_{com}, represents the probability of common phase; P_{med}, represents the probability of medium phase; P_{enc}, represents the enhanced phase; P_{apr}, represents the best possible solutions; β shows How much the enhanced node has more resources than the common node. θ shows the coefficients of the device. These are the probability coefficients used for the estimation of the cluster head configuration at every step. CH collection enhancement user provides us a description of these phases that CH updates every cycle and the network broadcasts useful data. The obtained data are aggregated by cluster heads. After this phase change, the base station generates the accumulated results.

Energy efficiency, limited nodes, and lower lifetimes are the key challenges of the current proposed routing protocols. In UWSN, most of the recent routing protocols are dependent on the flooding effect. It links several nodes with communications. In every other routing protocol, and specifically in UWSN where the Energy efficiency is very small, this type of routing protocol is not effective as it advances several iterations without a predetermined effective path. The energy efficiency of both distributor and receiver networks contributes to this form of approach. The efficient routing efficiency is therefore degraded by this method of the routing system. A 'clustering-based energy-efficient multipath adaptive routing protocol' for UWSN is proposed in this article. Energy performance, greater packet delivery, and enhanced network life are the primary objectives of this routing algorithm. The proposed system has increased energy usage and improved the longevity of the network. This prevents several packets from being sent to the next node within the network. This paper's proposed routing algorithm keeps track of the multi-sink UWSN architecture [34]. Multiple sinks are implemented in the preferred location in this form of UWSN design. On both the acoustic frequency modulation and wireless communications, different sink function. Underwater devices are widely distributed at a particular position in this routing protocol. A sink node, via a radio wave channel, interacts with another sink node.

This paper's suggested approach proves that when sensor nodes forward packets to multiple sink nodes, they will be forwarded. If the packet is properly performed between multiple sinks in each of the sinks, speed control would be found. This paper also suggests that the feature set of all network nodes, which is still called vertical distance, is known by any node. It is easy to measure the depth information of nodes across a sensor. For UWSNs, the suggested approach is termed an E2MR protocol. The purpose of this routing algorithm is to get more communication with energy efficiency and to operate the nodes for a longer life span. The proposed protocol would also lead to the network lifespan. By forwarding data packets to a pre-defined node, flooding can be prevented. This would also help prevent different versions from being made. The E2MR protocol is proposed to enhance the lifespan of the network, energy-efficient connectivity, and a higher packet-delivery ratio. The E2MR protocol would be able to benefit from the multi-sink underwater sensor network architecture. Multiple sinks configured between acoustic and radio-frequency base stations would get that kind of network. These sinks are implemented on the water surface. In the required feature map, underwater systems are installed in the water. These nodes are capable of gathering data and helping to provide the data to sink as well. A sink may connect effectively via radio channels with another sink. Users had also believed in our phase that a packet gets as early as some of the sinks implemented on the water surface are solutions provided.

V. EVALUATION RESULTS

With the aid of MATLAB simulation, the proposed scheduling methodology E2MR was being analyzed. This suggested routing protocol was connected with the current protocols, i.e. DBR, EEDBR, and also H2-DAB. The comparative analysis is determined by different criteria, such as the ratio of packet distribution, failure of the network path, lifespan of the network, the number of required nodes still, and overall energy consumption. The ranges of simulation set-up parameters that are required into effect when conducting the process are shown in Table 1.

- **End-to-end delay:** The number of times needed to send the packet from the forwarder node to the receiver node effectively. For time-critical circumstances, a smaller end-to-end delay is needed, while an end-to-end delay would be somewhat better for the scenario in which long-term control is provided.

- **Live node number:** Nodes that are in the service and get enough resources to forwarding packets are referred to as live nodes. It is significant that during a node that would not interact in systems are known, a node that is also involved in communication would drain the battery.

- **Packet delivery ratio:** The delivery ratio of packets is the total number of packets delivered out of all packets generated. For all types of networks, the packet distribution ratio is very significant.

- **Total energy consumption:** Total energy consumption is the total amount of energy consumed over a given period within the network.

Table 1. Evaluation Parameters

Parameters	Value
Sensor Nodes	1000
Sensor Network	250m * 250m
Energy Consumption	5j
Packet Size	1000 bits
Bandwidth	Mbps

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A comparison of the above-defined parameters is shown in Figure 2. The result illustrates that the end-to-end delay of H2-DAB is the maximum of all since it includes the phase of assigning dynamic attributes to all nodes in the network and adaptive attributes, and also other metrics such as energy-efficient, are correlated with it when conducting data-forwarding functions, creating an end-to-end latency. The figure above demonstrates the number of packets transmitted during the process of data processing, and several standards are evaluated for the transmission of packets. After defining cycles of data forwarding, the packet delivery ratio is calculated. The overall amount of energy that the four routing protocols generate during the simulation. The above graph represents that when using the Cluster head selection protocol, a node battery drops out easier as it accesses data packets to all nodes if they are far or closer.

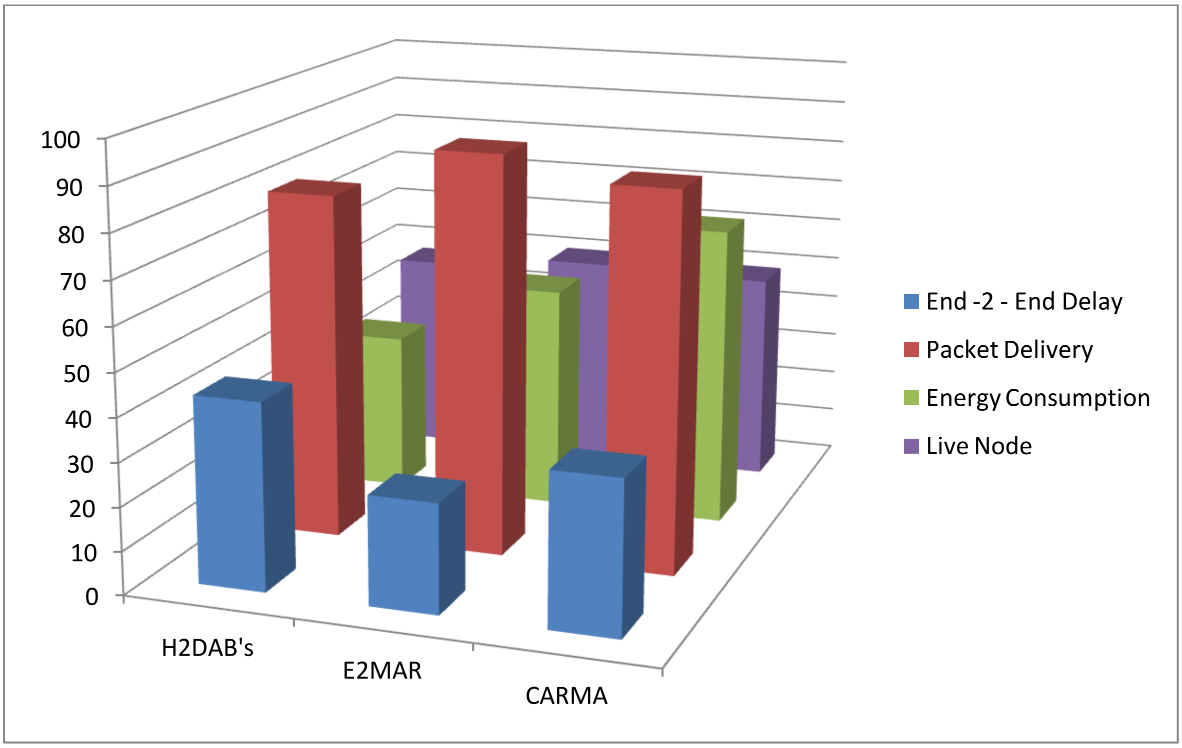

Figure 2. Comparison of Routing Protocols

VI. CONCLUSION

For underwater sensor networks, this paper has introduced a method routing protocol termed the energy-efficient multipath routing protocol. E^2MAR does not require any existing experience on the network or any other nodes' spatial features. A specific form of the table is generated in this process, termed a preference set. This table is generated with the aid of other nodes' energy-efficient and the length of the node of the sender. At the top of the table, nodes with a higher importance function are situated. The routing node collection is based on a combination of the sequence number. The numerous sinks that are implemented underwater will easily benefit from this protocol. Essentially, E^2MAR is planned for long-term monitoring. With a better network lifespan and a packet delivery ratio, this protocol was found to be energy-efficient. Interaction across UWSN's is really difficult because of the lower bandwidth and dynamic configuration. It is important to build fast-recovery algorithms and configuration controlling optimizations to improve its effectiveness. For retransmission of the same packet instead, lower bandwidth absorbs more resources. Energy performance, long-term control, and long network lifespan have been analyzed in E^2MAR.

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