A New Approach to Minimize Power Consumption in Underwater Wireless Sensor Networks

by Ahmed Q. Fahem

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Abstract. *This paper was presented based on a clustering method to minimize power consumption in underwater wireless sensor networks. The main objective of the proposed method is to choose an energetic path. The proposed clustering scheme operates with the round, so that each round consists of two phases the cluster head selection and the data transmission. After the end of each round which is called a t_{round}, the cluster head selection phase begins again. The obtained simulation results showed that the efficiency of the proposed method was better than L2ABF in terms of energy consumption and end-to-end delay.*

Keywords*: Wireless sensor network, Reduce power consumption, Clustering, Delay*

1. INTRODUCTION

The underwater wireless sensor networks have unique features due to their high bit error rate, high variable propagation delay, and low bandwidth of vocal channels in which the underwater acoustic communication channels are used instead of radio channels. A useful way for sending data is to use clustering. However, terrestrial clustering algorithms are not directly applicable due to the properties of media used in water. Also, some of these algorithms are based on uniform distribution, which due to non-uniform distribution is not suitable in the underwater environment, or are based on location information, which is a separate problem in underwater sensor networks [2]. There are also drawbacks in clustering algorithms designed for underwater sensors the most important of them is the lack of sufficient attention to node displacement and its effect on the cluster structure. Therefore, the design of the routing protocol considering the node's displacement and reducing energy consumption due to the limited energy of underwater sensor nodes and the difficulty of charging these nodes is the main issue. In this research, a new clustering method for underwater wireless sensor networks which is called Clustering routing in underwater sensor network (CR-UWSN) is presented, in which the feature of random displacement of nodes has been applied as a factor for selecting cluster heads. Due to the homogeneity of the nodes in the other proposed method, the advantage of this method is its simple mechanism in cluster-head selection due to the low energy and the limited computational power of the nodes. The following of this article has been organized in the below description: Section 2 examines the previous methods and their strengths and weaknesses in underwater wireless sensor networks. Section 3 introduces the proposed clustering method. Section 4 simulates and evaluates the proposed method, and finally Section 5 summarizes this article.

2. PREVIOUS WORKS

Routing is a basic concern in every network. The routing protocol is tasked with identifying and preserving the path. The majority of research in underwater sensor networks focuses on the physical layer, with limited attention given to the network layer, namely routing algorithms, which is a relatively new area of study. The primary significance of underwater wireless sensor networks is in energy efficiency. Due to the constrained capacity of the battery-powered sensor nodes, which are challenging to replace or recharge in the underwater environment, it is crucial to develop a scalable and energy-efficient routing protocol for this network, as stated in principle [3]. The subsequent section will examine underwater routing techniques.

The majority of the suggested routing methods for UWSN necessitate a dedicated network. Many of them include assumptions, such as having perfect knowledge of the location of the whole network, which is challenging in an underwater environment. They also assume the necessity of complex hardware, such as a pressure sensor, which each node must be outfitted with. The Hop-by-hop dynamic addressing-based (H2-DAB) protocol was offered as a solution that eliminates the need for the assumptions mentioned [4]. Nevertheless, due to the high usage of the nodes in close proximity to the sink, they experience a greater depletion of their power [5]. Nodes must be consistently maintained and routes need to be continually discovered to ensure uninterrupted mobility. A proposed solution to address this issue is the Vector-Based Forwarding (VBF) protocol [6], which eliminates the need for sensor node status information. It is presumed that every node possesses prior knowledge of its own location. Every packet carries the information about the source, sender, and ultimate destination nodes. During the virtual pipe-sending phase, it is presumed that nodes in closer proximity to the pipe will engage in transmitting the message. Nevertheless, this protocol incurs a hidden expense as nodes need to possess knowledge of their location and function. This necessitates the use of position assessment techniques. Additionally, in scenarios where only a limited number of nodes are deployed or scattered due to displacement, there may be a scarcity or absence of nodes along the designated path, while alternative paths exist outside of it [5]. Public broadcast requests might impose a significant burden on the network if the location of the nodes is not known in advance. A Focused Bream Routing (FBR) protocol was designed to address this problem [7]. It is presumed that every node in the spatial information network, as well as each source node, possesses knowledge of the end destination's location. Apart from this data, the spatial data related to the intermediate nodes is unnecessary. The routes are dynamically established as data packets go towards the destination, although this approach may encounter certain efficiency concerns. Displacement causes the nodes to grow thinner, hence preventing them from placed at a sending angle. Additionally, certain nodes are positioned outside of this range for sending, as mentioned in reference [5]. The Vector-Based Forwarding (VBF) protocol necessitates full spatial information of the sensor nodes in the network, a requirement that is unattainable in an underwater sensor network. The Depth-Based Routing (DBR) protocol requires simply sensor node depth information, rather than a comprehensive spatial information need. This protocol is particularly valuable in scenarios when there is a significant disparity in depth. An important benefit of the protocol is its ability to handle the mobility of network nodes without the need for a locator service [8]. However, this system is not without its drawbacks. One issue is that it relies on a greedy approach, which means that the thinness and densities of the nodes might negatively impact its efficiency [5].

Clustering-Based Routing Protocol

The Distributed Underwater Clustering Scheme (DUCS) has provided an informed method of energy distribution and random node displacement [9]. The cluster-head selection is performed by random rotation between the nodes whose purpose is to prevent the node's energy depletion. In addition to high packet delivery rates, DUCS has greatly reduced network overhead. However, this method also has disadvantages, such as this fact that the displacement of the node due to the flow of water affects the structure of the cluster, which in turn reduces its lifespan [5]. The clusters in the low-energy adaptive clustering hierarchy (LEACH) are generated by exploiting prior knowledge of uniform node distribution to determine the appropriate number of cluster heads. Underwater sensor nodes sometimes exhibit non-uniform distribution due to the influence of water movement, rendering LEACH inappropriate for UWSN. The clusters in a hybrid, energy-efficient, distributed clustering model (HEED) are generated without making any assumptions regarding the distribution of nodes. The cluster-head rotation system has been employed to provide load balancing. While HEED successfully maintains a satisfactory load balance within a limited region, the distribution of traffic load across different places remains imbalanced. To address these issues, a Distributed Minimum-Cost Clustering (MCCP) protocol was introduced with the objective of enhancing the longevity of the network [10]. However, the time it takes for the cluster to regenerate is measured in days and months, that impacts the efficiency of the network because nodes are replaced quickly [5]. Typically, the nodes located close to the sink exhibit rapid energy depletion in most proposed procedures. A Time-Critic Behavioral Rate (TCBR) method was developed to address this issue and provide consistent energy usage across the whole network. This protocol utilizes two categories of conventional nodes and relays. Upon the relay node reaching the range of communication of the normal node, the data will be transmitted. To ensure efficient transmission, every node stores the produced packets in its limited buffer until they are received by the relay node. This characteristic renders the TCBR algorithm unsuitable for applications that are time-sensitive [5]. The magnitude of energy loss during data transmission is directly proportional to the spatial separation between the transmitter and recipient. A challenge of multistage transmissions is that sensor nodes located around the sink are subjected to the processing of a substantial volume of data packets, resulting in rapid energy consumption. A novel LCAD clustering approach was introduced to address the problem [12]. The performance of LCAD is influenced by the configuration of the intended networks, particularly the cluster-head position. While this configuration is straightforward for terrestrial networks, it is not as feasible for underwater environments since node motion is continuous. Furthermore, this method lacks any provisions on the displacement of nodes [5].

3. PROBLEM DEFINITION

The clustered network is the division of the environment into non-overlapping clusters. In the suggested approach, the clusters consist of ordinary homogeneous nodes that only the cluster-head is involved in data transmission and the other nodes will go to sleep until the next step of cluster-head selection. In the proposed method, a number of source nodes that are data producers are located on the water floor. The dimensions of the L * L test medium are considered and the number of Sn wells is located at the water surface. The water flow velocity has also been assumed one to three meters per second. The distribution and displacement of nodes are also random.

4. The proposed CR-UWSN method

The proposed clustering scheme operates with the round so that each round consists of two phases of the cluster head selection and the data transmission. After the end of each round which is called a t_{round}, the cluster head selection phase will begin again. Considering that the cluster head node will be selected from the node located in the center of the cluster according to the random displacement of the nodes due to water flow and the possibility of the cluster head from the cluster, the t_{round} is calculated using Formula 1 where L indicates the environment depth, S_n is the number of water surface sink and Sw is the maximum of water flow velocity.

$$t_{round} = {}^{L}/_{[(S_n * S_w) * 2]} \quad (1)$$

Considering that the average depth of the ocean is two to three kilometers and the length of the vertical connection is up to 500 meters, the wave transmission range is also indicated by R, which can be calculated through Formula 2.

$$R = {}^{L}/_{S_n} \quad (2)$$

At the beginning of the clustering phase, the sink node transmits a packet to determine the first layer cluster head as a Request packet (RP), which contains the node layer ID. For this purpose, the good node first tries to select the cluster head in the center of the cluster by transmitting a wave at lower angles. The first transmitted wave angle is 10 degrees, and if no node is found in that angle, it will increase by another 10 degrees, and if another node is not found, it will increase by another 10 degrees. The sink node in the first step by sending the RP message puts the number of layer one into it (id = 0). Each node that receives an RP message and has a certain amount of energy (Having at least C_{min} joules of energy) sends in response to a Reply Request Packet (RRP) message.

4.1. Cluster Formation in the Proposed CR-UWSN Method

As it was mentioned in the proposed method, sink Sn at the water surface has been considered. After the cluster head is identified, the hello packet using the cluster head sends a message to the surrounding nodes to declare its existence, which contains its layer number. Then layer 1 cluster-head, increases the id by one unit and starts sending an RP message to the next layer for the cluster-head selection of the next layer. Each node that receives the RP message sends an RRP message in response, then sends the hello message to inform the other nodes of the cluster-head selection. According to the depth of L km, when the node ID reaches L / Sn, it doesn't send the RP packet. In this way, all the nodes are clustered at different depths and their cluster-head are identified. In each layer, by selecting the cluster-head and informing its nodes of that cluster with the hello message, the other nodes are informed about this issue and the nodes located in the cluster go to sleep by receiving this message, and only the cluster-head nodes send the received packet.

4.2. Data Transmission Phase In The Proposed CR-UWSN Method

In the data transmission phase, first a number of sources are located on the water floor in the N layer, then they send the collected data packets to the existing cluster-head in the N-1 layer. In this layer, except the cluster-head, the other nodes are asleep, so the existing cluster-head in this layer receives the packets and each cluster-head sends its packet to the cluster-head with lower depth, and then the recipient cluster-head sends a confirmation packet to the previous layer cluster-head. If there is no cluster-head and no confirmation packet, the cluster-head will send the packet again, but this time it will increase its range to a maximum of 500 meters.

4.3. Pseudocode and flowchart of the proposed CR-UWSN method:

In this section, in order to better understand the proposed CR-UWSN method, the steps of work procedure as pseudocode and flowchart have been shown in Figure (1).

1) Placing a specific sink Sn according to the selected topology at the determined intervals;
2) Determining the energy threshold equal to Cmin;
3) Sending an RP message from the sink with id = 0 in the L/ Sn meter range to determine the (CH);
4) The response of the sensor node with the RRP packet to the sink;
5) Informing the CH to the sensor nodes of cluster member with a hello message;
6) Sending a message (RP) from the selected CH to the next layer in order to select CH of the next layer;
7) Selecting all the clusters-head from different depths;
8) Going asleep of other nodes in the hello message recipient;
9) Transmitting data by the clusters-head;
10) In case of receiving a confirmation message, send the next packet and otherwise data transmission with a maximum range of 500 meters.
11) Ending the time duration of one round and repeating the clustering again.

Figure (1) Pseudocode and flowchart of the proposed method

5. SIMULATION AND EVALUATION OF THE PROPOSED METHOD

In this section, the CR-UWSN clustering mechanism is evaluated. For this purpose, the NS-2 simulation tool version 2.34 is used. In the following section, first, the simulation parameters are expressed, and then in the next section, the evaluation criteria are presented. In the third section, the simulation environment and scenario design have been provided and finally, in the fourth section, the simulation results are described.

5.1. SIMULATION PARAMETERS

The parameters required to simulate the presented method in Table (1) have been shown. In each time of the simulation, a number of parameters such as the number of the simulation sensor nodes can be changed and the results obtained of the simulation can be evaluated. In the scenario, the number of sensor nodes available in the network is considered equal to 225, 250, 350 and 400 nodes. The simulation environment used in this scenario for the simulation is 2000 m by 2000 m. The radio propagation range for each node is considered equal to 500 meters, its MAC layer protocol is IEEE 802.11. The scenarios considered in its proposed method (CR-UWSN) are considered and compared again with l2-ABF and MRP methods. The buffer size used in this scenario is 150 packets. The placement position of the nodes in this scenario is random.

5.2. EVALUATION CRITERIA

- **End-to-end Delay:** In wireless sensor networks, the length of time it takes for packets to be transmitted across the network from the source node to the destination node is called end-to-end delay.

- **Average Energy Consumption for Sensor Nodes:** The energy demand in wireless sensor networks is influenced by constraints on resources like power, energy, bandwidth as well as processing capability, and storage capacity in the nodes. Minimizing routing overhead and maintaining a high packet delivery rate are crucial concerns in this context. This metric quantifies the energy consumption of the node sensors during the process of routing.

- **Number of Deleted Packets:** The number of packets that have been deleted in routing operations for various reasons, including power outages or packet collisions.

5.3. SIMULATION ENVIRONMENT AND SCENARIO DESIGN

Based on extensive investigation and analysis of several scholarly works on simulation software, this paper concludes that the NS-2 simulator is the most suitable simulation for wireless networks of sensors of software flexibility as well as effectiveness. It is widely regarded as a very robust simulator for the simulation of sensor networks. The simulation utilized this simulator implemented in C++ code. The utilization of this particular simulator enables the implementation and simulation of several methodologies, as well as the observation of network performance. The parameter values utilized in this simulation are displayed in Table (1).

Table (1) Simulation parameters

Parameter	Value
Simulator	NS-2.34
Channel type	Channel/Wireless channel
Radio propagation model	Propagation/Two ray ground
Mac layer type	Mac/802.11
Queue interface type	Queue/Drop Tail
Traffic type	CBR
Antenna type	Antenna/Omni Antenna
Proposed method and Comparable method	CR-UWSN and L2ABF
Efficiency evaluation parameters	Energy consumption, deleted packets, and end-to-end delay
Simulation space area	First scenario: 2000 * 2000
Number of sensor nodes	225 to 400 nodes

6. Simulation Results

By performing the simulation on the suggested approach, it was verified that the suggested CR-UWSN method works very well. The simulation results show the performance of CR-UWSN in the end-to-end delay criteria, the amount of energy consumed by the sensor nodes, and the amount of packets lost in different conditions, which will be shown in the following:

The diagram of Figure 2 shows that the end-to-end delay is significantly lower for CR-UWSN compared to l2-ABF because the proposed method transmits the packet to the CH. But compared to the MRP method, the slight delay in the proposed method is greater due to the Localization-Free Multi-Layered Routing Protocol for Underwater Wireless Sensor Networks (MRP) method, the cloud node of each layer sends the packet to the cloud node at a lower depth, and that cloud node sends it to the sink.

Figure (2) End-to-end delay in the scenario of different numbers of sensor nodes

- **Average Energy Consumption**

One of the main issues that is described in the wireless sensor networks and has been considered in this project is the amount of energy consumption of the node, which directly will influence the lifespan of the network. As can be seen in Figure 3, the average energy consumption in the nodes in each simulation time in the proposed method (CR-UWSN) is lower than the l2-ABF method. The reason of this issue is that in the proposed method, since the collection and transmission of data are done by energetic clusters-head. However, in comparison to the proposed MRP method, the proposed method consumes more energy because the MRP method uses super nodes.

Figure (3) Average energy consumption of sensor nodes in the scenario of different numbers of sensor nodes

- **Packet Delivery Rate**

One of the main issues that is described in the wireless sensor networks and has been considered in this project is the packet delivery rate, which directly will influence the network performance. As it is shown in Figure 4, the packet delivery rate in all three methods is approximately equal.

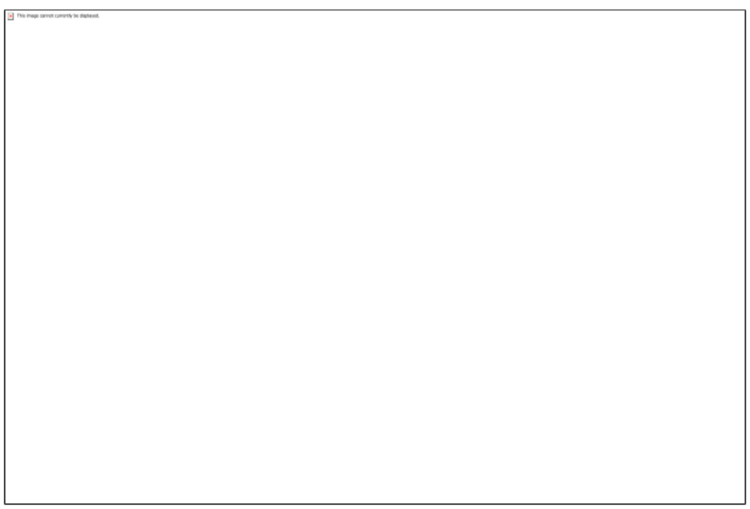

Figure (4) The amount of packets delivered in the scenario of different number of sensor nodes

7. CONCLUSION

This paper was presented based on a clustering method to minimize power consumption in underwater wireless sensor networks. The main objective of the proposed method is to choose an energetic path. The proposed clustering scheme operates with the round, so that each round consists of two phases of the cluster head selection and the data transmission. After the end of each round which called as t_{round}, the cluster head selection phase begins again. The obtained simulation results showed that the efficiency of the proposed method was better than L2ABF in terms of energy consumption and end-to-end delay.

8. REFERENCES

A. Harris III, M. Stojanovic, M. Zorzi. (2006). When underwater acoustic nodes should sleep with one eye open: Idle-time power managment in underwater sensor networks. In Proceedings of ACM International Workshop on Underwater Networks (WUWNet), Los Angeles, CA, USA.

Domingo, M.C. (2007). A Distributed Clustering Scheme for Underwater Wireless Sensor Networks nternational Symposium Ieee .

M. Ayaz, A. Abdullah. (2009). Hop-by-hop dynamic addressing based (H2-DAB) routing protocol for underwater wireless sensor networks. In: IFIP Networking, ICIMT.

M. Ayaz, I. Baig, A. Abdullah. (2011). A survey on routing techniques in underwater wireless sensor networks, Journal of Network and Computer Elsevier.

P Xie, Cui J-H, Lao L. (2006). VBF: vector-based forwarding protocol for underwater sensor networks.Networking. Networking technologies, services, and protocols; performance of computer and communication networks; mobile and wireless communications systems. Berlin/Heidelberg: Springer.

AaaJ. Jornet, M. Stojanovic, M. Zorzi. (2010). On joint frequency and power allocation in a cross layer protocol for underwater acoustic networks. Journal of Oceanic Engineering,Ieee.

H. Yan, Z. Shi, J. Cui. (2008). DBR: Depth-based routing for underwater sensor networks. In:Proceedings of IFIP Networking, Springer.

H. Daeyoup, K. Dongkyun. (2008). DFR: directional flooding-based routing protocol for underwater sensor networks. In: Proceedings of the OCEANS, ieee.

L. Cheng, Z. Jun. (2007). Distributed minimum-cost clustering protocol for under-water sensor networks (UWSNs). In: Proceedings of the international Ieee.

M. Ayaz, J. Low Tang. (2010). Temporary cluster based routing for Underwater Wireless Sensor Networks. In:Proceedings of the International Symposium in Information Technology ,ieee.

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