International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Volume 48, Issue 03, Quarter 03 (July-Aug-Sept 2019)
An Indexed and Referred Journal with Impact Factor: 2.80
ISSN (Online): 2319-6564
www.ijesonline.com

# Hierarchical Routing Based Energy Efficient Protocols in Underwater Wireless Sensor Network: A Review

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**Publishing Date: August 10, 2019**

**Abstract**

Underwater Wireless Sensor Networks are becoming popular day-by-day primarily owing to its adaptable as well as practical applications in real world such as ocean monitoring, mineral extraction, tactical surveillance and ocean monitoring etc. In a sensor network, efficient energy consumption by the sensor nodes is one of the most severe issues. As sensor nodes performs multiple tasks such as detection of events and routing the data to the surface nodes, so much of the battery of sensor nodes is consumed in receiving and transmitting packets. Henceforth, lifetime of battery is one of the determining factors of lifetime of a sensor node. To increase the lifetime of the sensor network, various hierarchical routing based energy efficient protocols are used. Due to the specific characteristics of underwater wireless sensor networks (UWSNs) such as dynamic structure of sensor nodes, narrow bandwidth, more energy consumption than sensor nodes at surface area, high latency etc., it is difficult to build energy efficient routing protocols for underwater wireless sensor networks. This paper presents a review on various hierarchical energy efficient routing protocols.

***Keywords:*** *Underwater Wireless Sensor Networks, Routing Protocols, Energy Efficiency.*

## I. Introduction

From last many decades, there has been a major interest in monitoring underwater environment for scientific, business and military activities. Real time monitoring is vital for many applications; this calls the need of building Underwater Wireless Sensor Networks (UWSNs). Underwater sensor network is an adaptable sensor network which depends on confined detecting and facilitated networking among large number of densely deployed sensors nodes both in underwater and at the surface.

The aim of sensor nodes is to perform collaborative tasks over a recommended area. Sensor nodes under the water can transmit important data with their sensing capabilities within the short distance [1].

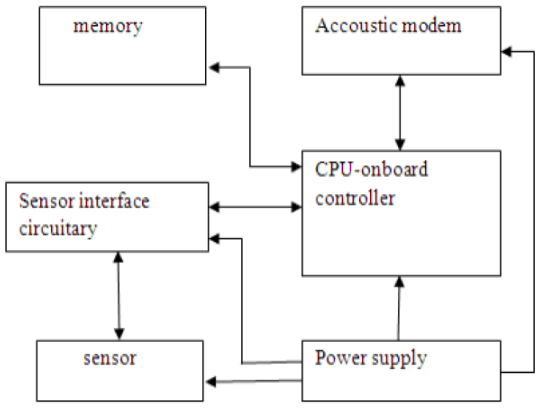


**Figure 1: Internal Architecture of Underwater Sensor Node**

A very significant role in underwater sensor network is played by routing techniques. It is very hard to relegate the global id's for large number of deployed sensor nodes. So, the conventional protocols are not relevant for underwater wireless sensor networks [4]. Underwater network is very dynamic network which is very specific to the kind of application where it furthermore faces challenges such as inadequate battery power, storage and processing capacity. These challenging characteristics make it very testing task to build up a routing protocol. In most of the cases, multiple sources are required to send their data to a specific base station. The primary limitation of sensor nodes is battery power. The sensors are battery-powered processing devices. The sensor nodes which are near to the sink exhaust more battery power and hence, eventually die. This causes dissection of the sensor network which ultimately reduces the lifetime of the network. It's very difficult to replace the batteries in numerous applications. Consequently, underwater wireless sensor network requires an energy efficient routing protocol. Underwater sensor network does not have any preset infrastructure and is very dynamic [5] [6].

## II. Related Works

**1. Han *et al.*, "Routing Protocols for Underwater Wireless Sensor Networks", (2015).**

The authors had presented a comprehensive review of underwater routing protocols. On the basis of route decision, the authors had classified the existing routing protocols into two categories. The advantages, disadvantages, and performance issues of routing protocols are also highlighted in this paper along with comparison of routing protocols on the basis of energy efficiency, path latency, multi- route capability, reliability, robustness, etc. After comparison, the authors had concluded that there are still many research challenges which have not been resolved yet [13].

**2. Ahmed *et al.*, "Energy Efficient Routing Protocols for UWSN: A Review", (2017)**

The authors had focused on energy efficient routing protocols for underwater wireless sensor network. They had elaborated the protocols operations contingent on its designed architecture, route detection, route maintenance, data forwarding, and energy consumption by sensor nodes. In numerical simulation method, the authors had observed that the ERP2R and R-ERP2R consumed lesser energy as compared to rest of the proposed routing protocols which shows that these protocols have used reliable methodology for energy efficiency [14].

**3. Javaid*et al.*, "An Enhanced Energy Balanced Data Transmission Protocol for Underwater Acoustic Sensor Networks", (2016)**

The authors had anticipated two novel routing protocols named as "EBET" and "EEBET" which are energy efficient. These novel protocols conquer the energy efficiency problem and distort inadequacies in presented underwater acoustic sensor network routing protocols. The utilization of efficient battery power helps in balancing energy levels of sensor nodes. The EEBET routing protocol helps in increasing the network lifetime by using battery power efficiently. The EEBET protocol had integrated depth threshold to restrict the amount of sensor nodes towards the sink and annihilate in reverse information transmissions. The efficiency of the two proposed protocols was superior in terms of some performance metrics than other existing protocols when measured using simulator [15].

**4. Domingo and Prior, "Energy analysis of routing protocols for underwater wireless sensor networks", (2008)**

The authors had proposed different performance metrics for routing protocols in UWSNsuch as packet relaying, undeviating transmission and clustering whereby energy consumption for each case was evaluated. The authors hasanalyzed that clustering based routing protocols accumulateadditional energy and thus their performance getsenhanced in shallow water. The packet handing-off technique results in lesser energy consumption in deep water therebyincreasing the network lifetime. This is in spite of the fact that it will increase unpredictability of routing protocols as well increased end-to-end delay. Design of more energy efficient routing protocols on the basis of clustering method will be possible in future which will maximize throughput and reliability as well as will minimize energy consumption [8].

**5. Zorz*iet al.*, "Energy-Efficient Routing Schemes for Underwater Acoustic Networks", (2008)**

The authors had proposed a class of routing schemes by considering every significant impact which

describe communication under the water such as propagation delay, bandwidth distance and power distance relationships. The authors had considered the impacts of the channel attributes on energy utilization and end to end delay after unreliable path and hop lengths which keeps on altering. This knowledge was then used to design and test some underwater routing protocols which reveal less energy consumption in comparison to other routing protocols. Furthermore, enhancement will be possible in optimizing and coordinating the protocols with idle time power running. They had suggested that other MAC layer protocolscan also be considered [9].

**6. Wang *et al.*, "An Energy-efficient Reliable Data Transmission Scheme for Complex Environmental Monitoring in Underwater Acoustic Sensor Networks", (2016).**

The authorshad proposed a new technique for energy competentinformation transmission whereby entire3D network can be divided into many small cubes and each of these cube forms a cluster. A head node is there in each cluster in the network, called cluster head which is accountable for data aggregation and broadcasting of all nodes of a cluster. The authorshad also proposed a new algorithm for cluster head selection. In this algorithm, the node having maximum residual energy and the shortest distance to base station is chosen as a cluster-head node. Simulation results show that "Energy-efficiency Grid Routing" based on three dimensional cubes (EGRC) consumes less energy and has more network lifetime as compared with LEACH, ELLEACH and ERP2R protocols [10].

7.**Xu *et al.*, "Comparison study to hierarchical routing protocols in wireless sensor networks",(2011).**

The authorshad presented a brief survey on several energy efficient hierarchical routing protocols which were analyzed as well as compared on the basis of various performance factors. In the last, the authors had summarized the problems of hierarchical routing protocols. One such common disadvantage was that they didn't support QoS in case of video and image data transmission. The authors had also described that development of hardware technology bears significant impact on design of routing protocols [16].

## III. Design Constraints for Routing in UWSNs

Due to a lesser amount of computing, radio and battery power of sensor nodes, various routing protocols in UWSNs are likely to accomplish the following necessities [7]:

- **Autonomy**: The supposition of a dedicated sensor node which controls the routing resources is not suitable in underwater environment because it can be an effortless point of assault. Since there won't be any central unit which can formulate the routing choice and therefore the routing actions are replaced with the sensor nodes.

- **Energy Efficiency**: Routing protocols in USWNs should expand the lifetime of the network while keeping up a high-quality grade of connectivity to permit the communication amid sensor network nodes. The battery substitution in the sensor nodes is infeasible because sensor nodes are randomly placed in underwater environment.

- **Scalability:**UWSNs are made up of hundreds and thousands of sensor nodes, so routing protocols in USWNs should be able to perform with these great numbers of sensor nodes.

- **Resilience:**Sensor networks may unpredictably stop working due to various environmental reasons or due to battery dissipation. Routing protocols should switch these events so that when a sensor node fails, then a subsequent substitute path could be formed.

- **Device Heterogeneity:**The majority of the applications of underwater wireless sensor network rely on homogenous sensor networknodes. But the benefits can be increased by introducing different types of sensors whereby nodes having different kind of processors, transceivers, power resources and sensor component may improve the characteristics of the sensor networks.

- **Adaptability:**Various applications of UWSNs canpermit nodes to deal with their own movements, the mobility of the sink node or the mobility of the event to sense. Routing protocols should beadjustable to these movements.

## IV. Energy Efficient Hierarchical Routing Protocols In UWSNs

The process of transmitting data from source nodes to a sink is a very challenging task especially in mobile nodes. More energy consumption is a major concern. At the same time, node mobility is handled.

One of the most critical issues of underwater wireless sensor networks is efficiency in terms of energy utilization. A sensor node generally utilizes their batteries for sending and getting data packets. Henceforth, battery lifetime is one of the key factors in determining the lifetime of the sensor network. A sensor network node plays the double job of both event detection as well as routing the information whereby a node depleting its battery can cause the dissection of the network in some network topology or may make various sensing region uncovered. In the majorityof applications, the replacement of battery may be incomprehensible due to various sensor network nodes and complexity of getting access to the detecting zone. Henceforth for increasing the life span of sensor network, energy efficient protocolsare utilized [8].

The key objective of hierarchical based routing protocols is to effectively keep up the energy level of sensor network nodes by incorporating them in multi hop communication inside a cluster and by performing information aggregation and mixture. Here, the whole network is partitioned into clusters whereby nodes in the same layer will do the same job. A few nodes are chosen as a cluster head of each cluster to manage tasks among the nodes. The cluster head is in charge of gathering and accumulating the data from nodes and then transmitting it to the base station. Clustering lessens the heap on the network by using the correlation among the data, conglomerating them which ultimately result in efficient energy utilization. There are some hierarchical protocols such as LEACH, TEEN, APTEEN, PEGASIS, LCADand so on [9]. Advantages, disadvantages and routing strategy of these protocols are discussed in table 1below [10].

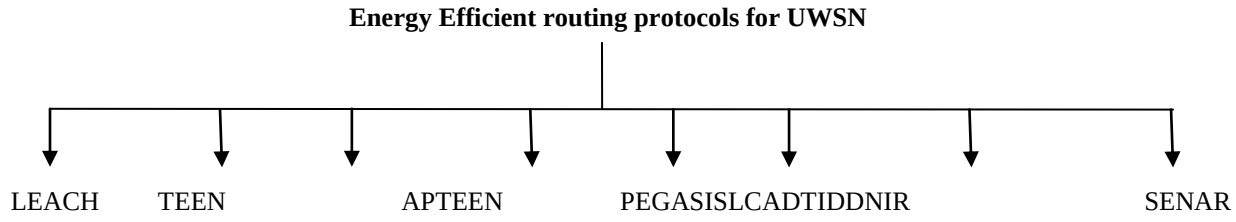

**Table 1: Energy Efficient hierarchical routing protocols.**

| Protocol | Routing strategy | Advantages | Disadvantages |
|---|---|---|---|
| LEACH (Low-Energy Adaptive Clustering Hierarchy) | Based on data fusion, cluster head node is generated arbitrarily by circular manner method. | Energy utilization is lesser due to usage of data fusion method. | Not reasonable for large scale networks.<br>Unsecure routing protocol. |
| TEEN(Threshold sensitive Energy Efficient sensor network) | Two thresholds are used here namely soft and hard which help in reducing the amount of informationtansmissionusing filter.<br>Soft threshold specifies the changing range of data packetswhile hard threshold value is the minimum value of data packets transmission speed. | Monitoring ofunpredictedprocedures and hot spots is possible.<br>Amount of data transfer is reduced by adjusting soft and hard threshold significantly.<br>Used in case of reactive underwater wireless sensor networks. | Not applicable in the applicationsin which periodic reporting of data is required.<br>Not secure. |
| APTEEN (the adaptive Threshold sensitive Energy Efficient sensor Network protocol) | The parameters issued by cluster head are adjusted by the cluster head itself. | Various parameters are changed according to need of users.<br>Successful data transmission by every node. | Unsecure routing protocol.<br>Does not support QoS. |
| PEGASIS(Power Efficient Gathering in Sensor Information Systems) | A structure chain of nodes is established using the location of adjacent nodes.<br>Using greedy algorithm, the nearest adjacent node is selected to send and receive data; each and every node became cluster head in turn. | Communicationcost is less.<br>Reduces the number of data transmission and communication volume using data aggregation method.<br>Network lifetime is increased. | Delay in data transmission is more.<br>Not applicable in real time applications.<br>Unsecure routing protocol. |
| LCAD(Location-Based Clustering Algorithm for Data Gathering) | Clustering method is used for selecting cluster head for data transmission.<br>Multi-hop method is used from source to sink node. | Energy dissipation is less due to multi hop method.<br><br>Network lifetime is increased. | Not suitable in underwater environment.<br>Does not support QoS. |
| TTDD( Two Tier Data Dissemination) | Grid network is constructed using location of nodes.<br>Location of adjacent nodes is calculated using greedy algorithm. | QoS is supported.<br>Single path is used.<br>Network lifetime is more. | Cost of computing and maintaining a grid is very high. |
| NIR(Node Information Routing) | Single path Greedy Forwarding Technique is used for forwarding the data from source node to sink node.<br>GPS system is used to find out adjacent nodes. | Energy dissipation is less due to greedy forwarding method.<br>Network lifetime is increased. | Data delivery ratio is less.<br>Localization problem is there. |

| | | | |
|---|---|---|---|
| SEANAR(Energy Efficient and Topology Aware Routing Protocol) | It is based on topology information and degree information of adjacent nodes for creating the routing judgment. The selection of the neighbor nodes for packets sending is based on higher weight calculation | Energy dissipation is less. | Higher node weight calculation method is not feasible in underwater environment. |

## V. Advantages of Energy Efficient Routing In UWSNs

There are various advantages of energy efficient routing techniques in UWSNs. Some of them are described below [11] [12]:

- High Durability of Sensors: Sensors Nodes can work along a long time; this will increase the durability of sensors under the water for long term.
- Low Maintenance: The long life of energy source of the node will lead to the long uninterrupted performance which will also reduce the requirements of regular maintenance.
- Cost Effective: If the sensors would be durable and require less maintenance, surely then overall cost of sensors under the water shall also decrease.
- Fewer Failures: The lifetime of Power Source will be enhanced by minimization of all constituting factors responsible for energy consumption in a node present in UWSNs. It will also reduce the number of failures which occurs due to the Power failure and presence of inadequate power in a particular node to perform the desired operation.
- Increased Performance: If the node would have a better source of power for longer time functioning in a particular process which requires fewer intervals for charging, then it will have a considerable impact on performance.

## VI. Conclusion

Interest in underwater wireless sensor networks is increasing day by day, and therefore related research studies are in advancement. Underwater environment has many restrictions which led to a very challenging task of designing energy efficient routing protocols. All routing protocols have the common objective such as decreasing end to end delay, decreasing resource consumption while increasing delivery ratio etc. Energy is the most concerning issue, so the network must keep up a longer life time to accomplish its objectives. In this paper, a review on hierarchical energy efficient routing protocols in underwater wireless sensor networks has been described. All these routing protocols have common disadvantages that they do not support QoS for video and image data. Additionally, the improvement of sensor hardware also has a considerable impact on blueprint of energy efficient routing protocols. The energy of the sensor network nodes cannot be re-increased normally, but the improvement in hardware technology makes it is a promising field.

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