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Proposing an Energy optimized routing protocol for UWASN based on clustering

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***Abstract*—The Importance of Underwater Wireless Sensor Network (UWSN) is increasing day by day. UWSN covers a vast area of application such as disaster prevention, assisted navigation, environmental monitoring or undersea explorations. UWSN consumes excessive amount of energy due to the use of acoustic waves to communicate which have some limitations such as limited bandwidth, high propagation delay, high bit error rate and more. Therefore energy consumption is the major concern at the time of designing a protocol for UWSN. Clustering mechanisms are commonly used in UWSN to design a balanced network that consumes less energy. In this paper we proposed an energy-efficient routing protocol for underwater 3D environments based on clustering. In this protocol, some of the nodes make a cluster where one node becomes cluster head and others are members of the cluster. A node becomes cluster head probabilistically based on the residual energy of the node. The simulation demonstrates that our proposed work uses less energy compared to the LEACH.**

***Index Terms*—UWASN,LEACH,WSN,Sensor network.**

I. Introduction

The implementation of sensor networks in the underwater environment has seen growing interest recently. In underwater environment, due to water absorption, the radio signal does not work well. In this regard, acoustic correspondence is normally applied as a reasonable arrangement in submerged sensor organizations. However, due to sound signals physical characteristics, acoustic channels are comprised of low available bandwidth, considerable propagation delay and very high error probability.

A. Application of underwater acoustic sensor network

- Ocean Sampling Networks: The sensor network can be deployed with autonomous underwater vehicle (AUVs) and can perform surveillance of the coastal ocean environment.
- Environmental Monitoring: UWASN can perform different kinds of contamination checking, for example, compound, atomic, natural and so on. It can screen sea waves and wind. It tends to be utilized to improve climate conjecture. It can likewise help in examining environmental change.
- Undersea Explorations: Underwater sensor networks can help detect underwater oil-fields or reservoirs, determine routes for laying undersea cables and assist in exploration for valuable minerals.
- Disaster Prevention: Sensor networks that measure seismic movement from far off areas can give information through waves.
- Assisted Navigation: Sensors can be used to identify hazards on the seabed, locate dangerous rocks or shoals in shallow waters.

B. Factors that affect the performance of the acoustic signal in underwater environment

In terrestrial wireless communication, radio frequency is used. But in the underwater environment we can not use the radio frequency. Due to the peculiarity of underwater environment, radio frequency can not work at low frequency, it can work at high frequency but needs a large antenna which is not possible. Optical transmission medium also can not be used underwater because of scattering problems. For all these reasons, the acoustic signal is appropriate for communicating in an underwater sensor network, but it is affected by some environmental factors. Some of these are environmental noise, doppler spread, path loss, multipath effects and long propagation delays [1]. We are describing some of these below.

- Path Loss: Path loss happens in two ways, attenuation and geometric expansion. Attenuation happens because of the transformation of acoustic energy into heat. Geometric expansion indicates the expansion of acoustic energy due to prolongation of the waveform.
- Noise: On account of underwater acoustic channels there exist various types of noise. Man made noise and ambient noise are some of its example. Man made noise is created by machinery and shipping activity. Ambient noise is a complex phenomenon regarding underwater communication. It can also be defined as a combination of different sources that cannot be uniquely identified.
- Multipath: As there are many paths available for the signal to flow, it creates a multipath problem.
- High energy requirement: Routing in underwater environment is extremely affected by high energy consumption. Since recharging a node in underwater is very difficult and sunlight can not be used as a source of energy in underwater environment, energy have to be efficiently

utilized. Developing a method which cut down the energy consumption in each node is very important.

C. Challenges in designing underwater acoustic sensor network

Major challenges in the design of underwater acoustic networks are [1]:

- The accessible data transfer capacity is seriously restricted;
- Propagation delay is five times higher than in radio frequency (RF) terrestrial channels and variable;
- High bit error rates and momentary failures of connectivity (shadow zones) can be encountered;
- Solar energy cannot be utilized and batteries can not be recharged;
- Underwater sensors are likely to failures because of fouling and corrosion.

II. Previous work

In paper [2], the author adopted a localized and distributed self-adaptation algorithm to get intended energy optimization. The algorithm permits nodes to measure the benefits of forwarding messages. If the benefit is less than the expected value, then the node discards the packet. The simulation showed using this technique; they managed to acquire energy optimization. In paper [3], they proposed an improved LEACH protocol for the underwater environment. They mentioned energy-optimized transmitting and receiving equations. Also, limit the position range for cluster heads and keep the number of cluster heads at 5. The protocol used a new measure for member nodes electing their cluster heads. It increased more energy effectiveness contrasted with LEACH.

In paper [4], They have made two new improvements in the LEACH. When some nodes become cluster heads in LEACH, it has to broadcast an advertisement message to all nodes in the network in a arbitrary way. It reduces the energy a lot and also creates collisions. The paper mentioned a mechanism where the broadcast message is sent in a controlled way. This improvement has some insufficiency; to overcome it, they proposed a new technique where a node will act as a control node. The control node will accomplish two work, to eliminate collision between advertisement messages and to broadcast advertisement messages in favor of cluster heads. Both improvements acquired better energy stability than LEACH.

In paper [5], They bring in a distributed scheme for three-dimensional underwater environments called Distributed Underwater Clustering Scheme(DUCS). It is based on the clustering methodology. The DUCS works are divided into two steps. The first step is called setup and the second is called network operation. In the first step all the clusters will be created and in the second step data transfer will be held. It is also a multihop protocol that means when cluster heads will send packets to sink it may not directly go to the sink instead through another cluster head. The protocol is simple and simulation shows its energy efficiency. But it has some complications. The deployed sensor nodes in the underwater environment are moving with the water current. For this reason, the cluster structure can not remain constant. Also, in the paper, one cluster head can send information directly to another cluster head, but due to node movement with the water current, two cluster heads may move away and can't communicate directly all the time.

III. Proposed methodology

A. What is LEACH

LEACH was one of the primary protocols that was applied in wireless sensor network. The main purpose of LEACH was to prolong the lifetime of the network. It chooses cluster heads arbitrarily and periodically to load the energy over the whole network equally. LEACH's procedure divides into rounds, and

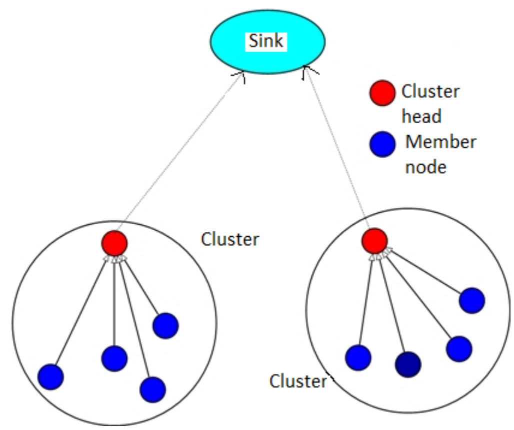

Fig. 1: Working principle of LEACH protocol

every round has two phases, the set-up phase and the steady-state phase [6]. In the set-up phase, it selects cluster heads for that round. In order to do this, a random number from that point forward is chosen and a threshold value is calculated. If the random number is greater than the threshold value, then the node will be chosen as a cluster head for that round. In the steady-state phase, all noncluster head nodes choose their cluster head based on signal strength. At first, the cluster head chosen for that round sends a broadcast to all non-cluster head nodes. A non-cluster head node will select a node as its cluster head where it needs less energy to send messages. In this process, the CSMA protocol is utilized. After that, every cluster head gives a different time slot to their cluster member to send data using TDMA. When all cluster members send data to their respected cluster head, the cluster head aggregates all data and sends it to the base station.

We choose the clustering method of LEACH protocol to implement in our protocol. The clustering mechanism divides the network into more than one cluster which can cover all the nodes in the network and communicate with each other. In order to balance energy consumption of the network, it periodically selects cluster head nodes for each cluster. We derived the transmitting and receiving equation from [7]. The required energy to transmit l bits over distance d is,

$$E_{TX}(l,d) = lE_{elec} + lT_bCHde^{a(f)d}$$

and to receive l bit,

$$E_{RX}(l,d) = lE_{\text{elec}}$$

where Tb the bit duration, E_{elec} is the unit energy consumed by the electrons to process one bit of message, *a(f)* is the frequency dependent medium absorption coefficient. [7] To get the optimum cluster we set the number of cluster heads to 5. We determine a formula for residual energy of a node. By using this formula we can choose a node which has more residual energy than others. If we choose a node which has less energy as a cluster head then it will be dead soon. It will damage the network rapidly. In the clustering method, before the start of the first round, each node *'i'* generates a random number between the interval [0,1]. If the number is found to be less than a threshold value T(n) given by the equation, then that node will become CH for that round.

$$T(n) = \begin{cases} \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)}; & \text{for all nodes(n)} \\ 0; & \text{Otherwise} \end{cases} \quad [6]$$

After the first round all nodes use some of their initial energy. To choose cluster heads for remaining rounds we use a slightly different formula to calculate threshold value. Which is,

$$T(n) = \begin{cases} \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)} \times \frac{E_{\text{residual}}}{E_{\text{intital}}} \text{k}_{\text{opt}}; \text{for all n} \\ 0; \ \text{Otherwise} \end{cases} \quad [8]$$

Where $E_{residual}$ is the remaining energy level of the node and $E_{initial}$ is the initial assigned energy level. The optimal number of cluster K_{opt} can be written as,

$$k_{opt} = \sqrt{n/2\pi}\sqrt{\frac{E_{fs}}{E_{anp}d^4(2m-1)E_0 - mE_{DA}}}M \ [9]$$

'M' represents the network diameter and Eo is the initial energy supplied to each node.E_{amp} is the energy dissipation for receiving and E_{fs} is the Energy dissipation for free space model.

IV. Experimental setup

We conducted the simulation on MATLAB version R2015a. a list of the different parameter that is used for this experiment are given below:

Table I. Parameter

Parameter	*Meaning*	*Value*
x,y,x	Node position	100,100,100
Sink x,y,z	Sink position	50,50,25
n	Node number	100
p	probability	0.2
$E_{initial}$	enitial energy	0.1j
L	Packet length	4000 bit
E_{DA}	Data aggregation energy	5*0.000000001j
E_{ELEC}	Energy requied by node to receive each data packet	50*0.000000001j
rmax	Total round	200

V. Result

The result shows that our proposed protocol is giving better performance in terms of the number of total Dead nodes and residual energy of the total network.

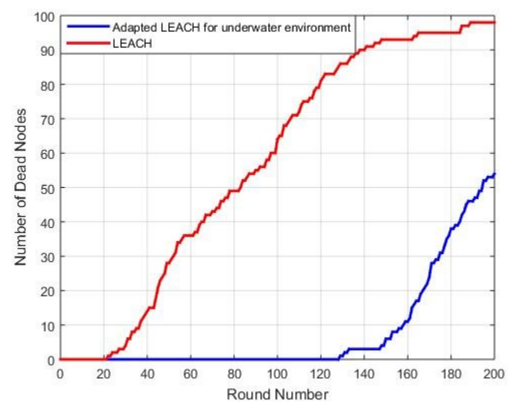

Fig. 2: Comparison on the basis of Dead node

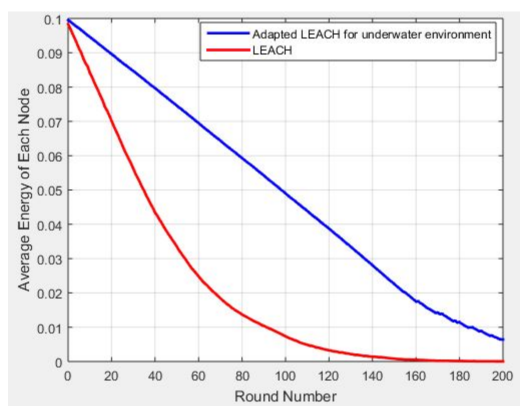

Fig. 3: Comparison on the basis of residual energy

In fig. 2, LEACH lost its first node at round number 30. After that, it was continuously losing its nodes. It lost almost half of its nodes within 90 rounds and in under 170th round all the nodes were dead. On the other hand, our proposed protocol showed very advanced performance compared to LEACH. For the first 100 rounds, we did not lose a single node. It was encountered with its first dead node at round number 125 wherein LEACH had lost around 80 nodes. We finished 200 rounds with less than 60 dead nodes.

fig. 3 demonstrate which protocol prolongs the network most. After 20 rounds, the average energy in each node in LEACH is around 0.07 Jules. The network was losing its energy drastically. Within 100 rounds, the network lost around 0.9 Jules and eventually, all the energy was consumed around 170th round. In our protocol, it showed very balanced result when it comes to extending the lifetime of the network. At the 70th round, our protocol lost one-third of the energy where at this stage LEACH lost more than two-thirds of its energy. When nodes consumed all the energy in the LEACH protocol, we had enough energy to continue the network. We completed 200 rounds with each node having sufficient energy to continue their work.

VI. Conclusion

It is very difficult to recharge any node in the underwater sensor network if the node dies. For this reason, energy consumption plays the main role in any routing protocol. In this work, we have designed an underwater wireless sensor network based on clustering methods in a 3D underwater environment. In the clustering method, a bunch of nodes forms a cluster where one node is assigned as the cluster head. Cluster heads are probabilistically selected; members of the cluster choose their cluster head where transmission costs will be minimum. The key feature of our work is that we used the residual energy of a node before making it a cluster head. While our main focus was to make the network more energy-efficient, the simulation result shows that our proposed protocol significantly extends the network lifetime and forms a cost-effective network.

VII. Future work

In this paper, the nodes which are established underwater are stationary; this protocol can be implemented with AUV's. By adding more parameters such as latency and throughput, the nodes performance can be measured more precisely. Although, this protocol does not confine the position range for cluster heads, if a node stays at the end position of the network then when it will send a packet to sink large energy will be needed which will ultimately damage the node. Consequently, the lifetime of the network will decrease. But if the position range for cluster heads can be confined then it will reduce the rate of damage. Solving this issue is our main future objective.

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