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Underwater Sensor Networks: A Proposed Routing Protocol to Increase Reliability and Power Efficiency

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Abstract: *Underwater wireless sensor networks consist of a certain number of sensors and vehicles that interact to collect data and perform collaborative tasks. The sensor network consists of static and mobile underwater sensor nodes. The nodes communicate point-to-point using a novel high-speed optical communication system integrated into the TinyOS stack or other small operating system, and they broadcast using an acoustic protocol integrated in the OS stack. The sensor nodes have a variety of sensing capabilities, including cameras, water temperature, and pressure. The mobile nodes can locate and hover above the static nodes for data mulling, and they can perform network maintenance functions such as deployment of sensor nodes, relocation of sensor nodes, and recovery from failures. Underwater wireless sensor networks have been used widely in many applications where sensor nodes collaborate with each other to execute monitoring tasks with reliability and energy-efficiency In this work, we will design a routing protocol that will enhance the packet transfer rate from nodes to base station using hierarchical routing technique. The proposed work is to design a routing protocol which will enhance packet transfer rate and the results will be compared with other routing protocols of same category like SEP.*

1. Introduction

Underwater Wireless Sensor Networks (UWSNs) are emerging as a key solution for a wide range of potential applications, such as monitoring of the environment and critical infrastructures, coastline protection, and prediction of underwater seismic and volcanic events [1, 2]. However, we are still far from having reliable and efficient underwater solutions which can be actually deployed in field. More robust and reliable technologies and communication solutions are needed. These solutions need to adapt to the underwater channel dynamics while trying to reduce the energy consumption of the nodes in order to prolong the network lifetime [3-5]. The replacement of node batteries in offshore deployments can in fact introduce high cost and complexity [6].

2. System Architecture

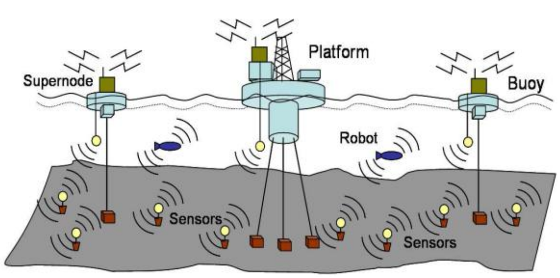

Figure 1: Underwater Sensor Network Architecture [6]

In Figure 1, we see four different types of nodes in the system. At the lowest layer, the large number of sensor nodes is deployed on the sea floor (shown as small yellow circles). They collect data through attached sensors (*e.g.*, seismic) and communicate with other nodes through short-range acoustic modems. They operate on batteries, and to operate for long periods they spend most of their life asleep. Several deployment strategies of these nodes are possible; here we show them anchored to the sea floor. (They could also be buried for protection.) Tethers ensure that nodes are positioned roughly where expected and allow optimization of placement for good sensor and communications coverage. Node movement is still possible due to anchor drift or disturbance from external effects [6].

2.1 Challenges and Issues

Major challenges in the design of underwater acoustic networks are [7]:

1. Propagation delay is five orders of magnitude higher than in radio frequency (RF) terrestrial channels and variable;
2. The underwater channel is severely impaired, especially due to multipath and fading problems;
3. The available bandwidth is severely limited;
4. High bit error rates and temporary losses of connectivity (shadow zones) can be experienced;
5. Underwater sensors are prone to failures because of fouling and corrosion;
6. Battery power is limited and usually batteries cannot be easily recharged, also because solar energy cannot be exploited.

The issues are:

1. MAC layer: In network packets are move from one layer to another layer because of MAC layer. Underwater nodes have extremely-limited bandwidth, long delay so they share available resources. Medium access control layer is used to access the underwater acoustic channel [7]. MAC layer schedules each node to access physical medium. MAC layer also setup some parameters and determine resources that physical layer could have.
2. Network layer: Network layer contain the information about the routes. It's responsible for the routing packets and it contains the information of path between sender nodes to destination node. It is having two routing methods one is virtual circuit routing and the second is packet switch routing [8]. In first, the network use virtual circuits to decide the path between sender and receiver. And in second one every node

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that is part of transmission has its own routing decisions. Now the packet switching has further two types. One is proactive routing and another is reactive routing.

3. Physical layer: Physical layer link with basic hardware and hardware transmission technologies. UAN is unique because of physical channel [9]. For underwater channel electromagnetic wave band have high attenuation but go through only small parts of long-wave bands. So here we need a large antenna and high transmission power. The communication is done in underwater with acoustic signal because acoustic signals can travels at long distance in underwater.

4. Application Layer: Application layer provides the network management protocol. This layer is used for the problem partitioning and resource allocation [10]. It s also use for Synchronizing communication, detecting resource availability and identifying communication partners.

3. Proposed Algorithm

The foundation of proposed routing technique lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, proposed routing technique utilizes the base station to control the coordinated sensing task performed by the sensor nodes. In proposed routing technique the following assumption are to be considered.

- A fixed base station is located far away from the sensor nodes.
- The sensor nodes are energy constrained with a uniform initial energy allocation.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- All sensor nodes are immobile.

The radio channel is supposed to be symmetrical. Thus, the energy required to transmit a message from a source node to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

Algorithm for Reliable and Power Efficient Routing

1. Initially, base station is at position 300 X 300 and 500 nodes are setup in a particular region (300 x 300) and each node has equal energy (0.5 joule).
2. A percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes, and the rest (1−m)×n as normal nodes. We assume that all nodes are distributed randomly over the sensor field.
3. Suppose that Eo is the initial energy of each normal sensor. The energy of each advanced node is then Eo* (1+α). The total (initial) energy of the new heterogeneous setting is equal to: n * Eo * (1 + α * m)

So, the total energy of the system is increased by a factor of 1+α * m.

(i) each normal node becomes a cluster head once every 1 popt · (1+α ·m) rounds per epoch;

(ii) each advanced node becomes a cluster head exactly 1 + α times every 1 popt· (1+α·m) rounds per epoch;

and (iii) the average number of cluster heads per round per epoch is equal to n × popt

4. Cluster Head Election for normal nodes is based on following equation:

$$T(s_{nrm}) = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}\cdot(r \bmod \frac{1}{p_{nrm}})} & \text{if } s_{nrm} \in G' \\ 0 & \text{otherwise} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where r is the current round, G' is the set of normal nodes that have not become cluster heads within the last 1/pnrm rounds of the epoch, and T(snrm) is the threshold applied to a population of n · (1 − m) (normal) nodes. This guarantees that each normal node will become a cluster head exactly once every 1/popt· (1+α·m) rounds per epoch, and that the average number of cluster heads that are normal nodes per round per epoch is equal to n · (1 − m) × pnrm.

5. Cluster Head Election for advanced nodes is based on following equation:

$$T(s_{adv}) = \begin{cases} \frac{p_{adv}}{1-p_{adv}\cdot(r \bmod \frac{1}{p_{adv}})} & \text{if } s_{adv} \in G'' \\ 0 & \text{otherwise} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where G" is the set of advanced nodes that have not become cluster heads within the last 1 padv rounds of the epoch, and T(sadv) is the threshold applied to a population of n x m (advanced) nodes. This guarantees that each advanced node will become a cluster head exactly once every (1/popt)x((1+α·m)/(1+α)) rounds.

6. Based on above equations and conditions, nodes sends the data to their respective cluster heads and energy consumption will be calculated.
7. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated for each node and cluster heads.
8. In round 2, the nodes will become cluster heads according to probability condition i.e. according to minimum distance from base station and threshold energy.
9. After selection of cluster heads, Nodes sends the data to their respective cluster heads, that will be selected according to the minimum distance of a particular node from cluster heads and energy consumption will be calculated.
10. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated.
11. Ten nodes will also go in sleep mode to enhance the network lifetime if their energy is less than 1 nJ. If the numbers increase then ten, then the nodes will come in active mode and send the data to nearby cluster head.

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12. This process will be repeated until the whole network gets down or number of rounds finished. Performance will be evaluated according to parameters like network lifetime, energy dissipation, data packets sent etc.

4. Implementation and Results

4.1 Parameter Value

Network field: 300x300m
N (Number of nodes): 500
Initial energy: 1 Joule
Eelec (E.Dissipation for ETx&ERx):50 nJ/bit
ε fs (free space): 10 pJ/bit/m^2
εmp (Multipath fading): 0.0013 pJ/bit/m^4
EDA (Energy Aggregation Data):5 nJ/bit/signal
Data packet size: 4000 bits
Tool used for implementation: MATLAB R2016a

4.2 Results

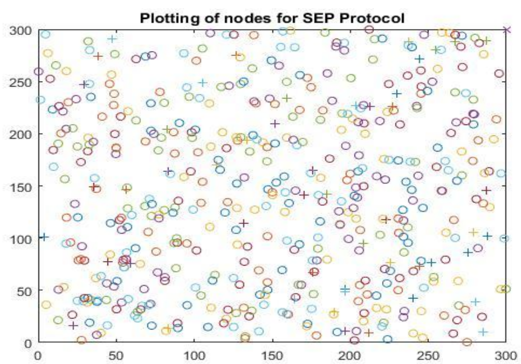

Figure 2: Deployment of nodes and base station for SEP

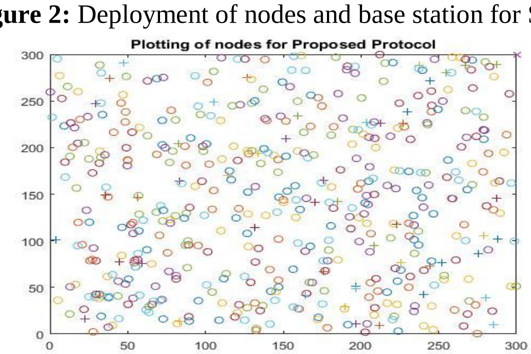

Figure 3: Deployment of nodes and base station for Proposed Protocol

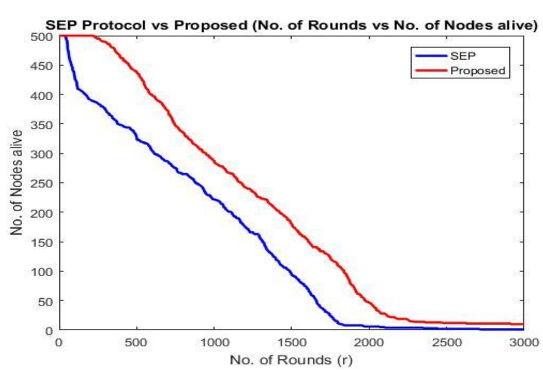

Figure 4: Number of Rounds vs Number of Nodes Alive

Figure 2 and Figure 3 shows the deployment of nodes and base station in a particular region. The region we have taken for simulation is 300m x 300m. The 'o' symbol denotes the nodes and 'x' symbol denotes the base station (sink). The position of nodes is taken similar in SEP as well as in proposed protocol.

Figure 4 shows the comparison of routing protocols SEP and proposed routing in terms of number of nodes alive. Figure 4 shows the overall lifetime of the network. Here, we can observe that proposed routing technique performs better as compared to SEP protocol.

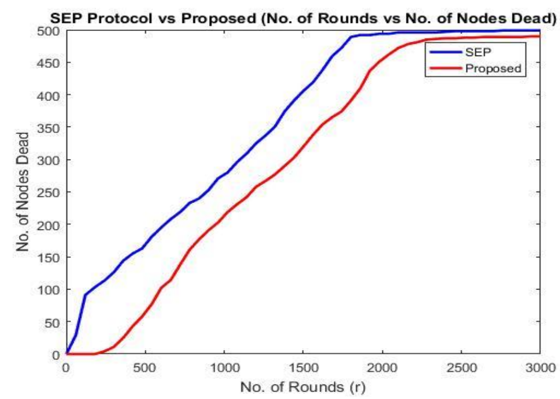

Figure 5: Number of Rounds vs Number of Nodes Dead

Figure 5 shows the comparison of routing protocols SEP and proposed routing in terms of number of nodes dead. Here, we can observe that proposed routing technique performs better as compared to SEP protocol. Figure 4 and Figure 5 shows the lifetime of the network. It shows that how energy of the network consumes step by step and finally whole network goes down. It can be observed from the figure 4 and figure 5 that, proposed reliable and power efficient routing technique consumes less energy and sustain more number of rounds as compared to SEP protocol.

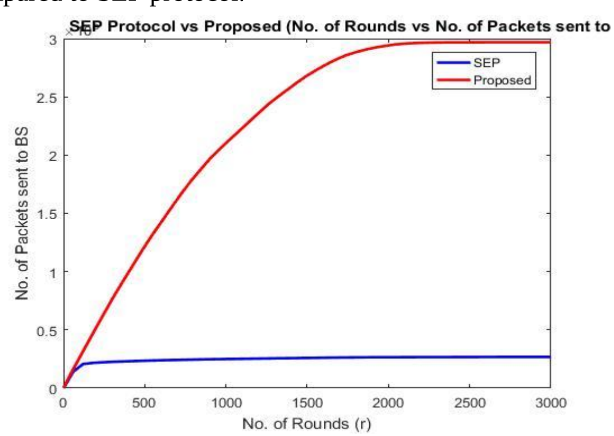

Figure 6: Number of Rounds vs Data Packets sent

Figure 6 shows how much data will be sent from nodes to SINK or Base Station. From figure 6, we can observed that, in SEP protocol data sent to base station is relatively less as compared to reliable and power efficient routing (proposed routing) technique.

5. Conclusion and Future Scope

This new routing protocol named Reliable and Power Efficient Routing Protocol (proposed routing technique) which is hierarchical routing. Hierarchical routing is generally categorized as two types; centralized or non-centralized. In non-centralized hierarchical routing, sensor nodes self configure them for the formation of cluster head. While self configuring, the nodes are unaware about the whole logical structure of the network. But in proposed routing technique, the base station first collects information about the logical structure of the network and residual energy of each node. So, with the global information about the network base station does cluster formation better in the sense that it has information about the residual energy of each node. Finally, proposed routing technique is compared with already developed routing protocol SEP by the help of MATLAB. A comparison between two is done on the basis of energy dissipation with time, data packet sent and the system lifetime of network.

In WSN, hundreds or thousands of sensor nodes are randomly scattered in the sensor field. These nodes sense the data and send this sensed data to the cluster head (in case of hierarchical routing) or directly to the base station according to the TDMA (time division multiplexing access) given by cluster head or base station respectively. But there is no security and authentication while communicating. So this can be another research area where this can be considered. So in future, security can be applied to proposed routing technique.

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