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# DUAL MODE COMMUNICATION FOR UNDERWATER SENSOR NETWORK

**Upendra Rawat[1] , Vivek Agrawal[2]**

*Information Technology, Galgotias College of Engineering & Technology Greater Noida, (India)*

*Information Technology, Galgotias College of Engineering & Technology Greater Noida, (India)*

## ABSTRACT

*Research in Underwater Acoustic Sensor Networks (UW-ASNs) has much fledged in last decade. Routing in underwater Acoustic sensor networks differs from routing in terrestrial wireless sensor network. This is due to challenges followed by UW-ASN, limited bandwidth in water, node mobility due to water currents, and potential delay in data packet transmission. The radio waves propagate through conductive salty water only at extra low frequencies (30 − 300 Hz), which require large antennae and high transmission power.*

*High energy consumption and small range of communication is a challenge for under water acoustic communication with limited bandwidth in water, but radio waves propagate at low requirement of energy with larger communication range. We proposed a Min Node Floating technique which uses both acoustic communication in water as well as radio communication on above the surface of water with depth adjustment system to switch between them for reducing the high transmission power.*

***Keywords: Acoustic Communication, Energy Efficient Underwater Acoustic Sensor Networks, Radio Transmission.***

## I INTRODUCTION

Underwater wireless sensor networks have applications ranging from studying marine life, climate monitoring, prediction of natural disasters, pollution control, search and survey missions, and potentially many other unexplored uses. However, one of the main challenges that underwater wireless sensor networks face is communication.

There are four main types of communication used in underwater sensor networks, acoustic, radio, satellite, and optical communication. Acoustic communication is the only long range underwater option of these four communication mediums. However, it suffers from a low data-rate, high energy consumption, and many complex problems. Radio communication is typically the dominant communication medium outside of water. It provides long distance communication with high data-rates. However, it cannot be used underwater because water absorbs and disperses the vast majority of radio frequencies. Satellite is another long range surface communication method. However, scalability issues arise as satellite communication is expensive. Optical communication and satellite communication are not explored in this paper; we chose to primarily focus on radio communication and acoustic communication.

In this paper we define a simulation environment that describes an underwater network where nodes are able to efficiently surface to use radio communication. Using this environment we determine paths for radio communication on a line topology in a multimodal system. We implement an acoustic and radio based algorithms to facilitate decisions about communication. The agents emulated in this paper have depth control capabilities and two wireless modems. The first modem is an acoustic device that allows any two nodes within range to communicate underwater, but at a high energy cost. The second is a radio that cannot be used underwater, but requires relatively little power. The acoustic and radio devices modeled are described in Table 1, with values taken from [1]. The depth adjustment system described in [1, 2] consumes a large amount of power compared to either modem.

**Table 1: Summary of Acoustic and Radio modem Attribute**

| | **Acoustic** | **Aerocomm AC4790** |
|---|---|---|
| **Transmit Power** | 5W, 113.6mJ/bit | 1W, 0.16mJ/bit |
| **Data Rate** | 22b/s | 7.2kb/s |

Our primary concern is then: how do we pass a message from source to target node within a network in an efficient way? As shown in [1, 5], there is a clear cut-off of when the cost of rising will be less than the cost of forwarding a large message acoustically. In reference to that, the algorithm defined provide a method of selecting who will rise and participate in radio-message forwarding. We determine that distributed algorithms using only local information can perform at or near the level globally optimal algorithms for determining members of the radio path. This paper contributes to the field of underwater networks by demonstrating the effectiveness of greedy routing schemes that use locally available information, and by providing a simulator in which they can be tested.

As show in Table 1, radio communication is both faster and less expensive. In our context, the problem with radio communication is the cost of surfacing; using the depth adjustment system. The average cost of ascending or descending motion, is determined to be 15000mJ/m or 15 Joules/meter. All other energy costs are in the mJ, or in some cases µJ range. Rising then dominates cost until message size increases above a threshold.

## II RELATED WORK

Our system takes advantage of dual mode communication methods to within an underwater network. We develop an idealized simulation environment that eliminates many of the challenges of networking, and assume peer discovery has already been completed. The underwater sensor nodes that we model are AquaNodes .We utilize the AquaNodes depth adjustment, acoustic communication, and radio communication capabilities. The remainder of this section will discuss the prior work in underwater sensor network communication, and the AquaNode platform. As we function on an abstract level rather than handling specific issues of implementing networked systems, we draw from algorithmic studies and rely on values from work done with physical systems.

### 2.1 Wireless Underwater Networks

It is common for sensor networks to rely on gateway nodes to handle large amounts of data over long ranges [6–8]. Many underwater sensor networks leverage surface nodes for long-range, high-throughput communication channels [2]. For instance, the US Navy deployed a system called SeaWeb [9] to test deployments of multi-node underwater networks with static and mobile nodes. SeaWeb had a number of radio/acoustic ("Racom") nodes at the surface that could communicate both acoustically and with radio to satellites, ships, or shore. These Racom nodes also had the advantage of anchoring localization systems since they have access to GPS. Using a surface gateway node is one of the more practical methods to obtain information from an underwater network [5]. Where to place surface gateway nodes to minimize energy and end-to-end delay given a set of underwater nodes with known positions has been examined using integer linear programming [12]. With these types of systems, the overall bandwidth of the system is limited by the acoustic channel, since all nodes need to transmit acoustically to a radio gateway node. Another option for obtaining data from an underwater sensor network is to use an underwater vehicle to collect the data. Underwater gliders surface periodically and send data collected along their trajectories from underwater sensor network back to land [4].

What could be considered a flaw of these surface-gateway systems is that the acoustic modem limits communication. All nodes must transmit acoustically to have data forwarded out of the underwater part of the network. This places a natural limit on the rate at which data can be extricated; in an ideal system data could be retrieved at the maximum rate of the modem, but a real system would face packet loss. To mitigate this problem, work has been done to introduce underwater vehicles to these systems and retrieve data as policy dictates. These vehicles collect data along a path and occasionally rise to send data via radio [1,12].

### 2.2 AquaNode

The sensor nodes that we use for simulation are AquaNodes [4]–[6]. In normal operation an AquaNode is anchored to the seafloor and floats in the water mid-column sensing the environment. AquaNodes have the ability to adjust their depth in the water, have three types of communication mediums, and multiple sensors. The depth adjustment system allows for the AquaNode to dynamically rise and descend in the water column. Figure 1 shows the AquaNode and the winch based depth adjustment system and Figure 2 shows the details of the depth adjustment system. AquaNodes are capable of radio communication at 57kbit/s within 3km, acoustic communication at 300b/s within 400m, and optical communication at 3Mb/s within 3m [5]. Radio communication is only used when the node surfaces while acoustic and optical are used underwater. For sensing, each AquaNode has a pressure sensor, temperature sensor, color camera, and the ability to add additional sensors [23]. The simulation environment models the unique features of the AquaNode, the energy consumption values, and the communication ranges. Our work looks to utilize the depth adjustment system and surface radio communication of the AquaNode for data transmission.

The system we implement is different in that each node is capable of surfacing to send its own data or relay transmissions from its neighbors. Issues associated with acoustic gateways are removed in this scenario. We implement Min Node Floating algorithms, and compare the results of this with dijkastra algorithm. The proposed approach use radio frequency communication over water surface by using depth adjust system. The proposed approaches are similar to greedy geographic routing in land-based systems which are near-optimal in dense networks, and varying implementations have been demonstrated to improve performance in challenging and dynamic environments. Given the high performance of greedy methods in land environments, we are motivated to explore their loose analogues in the underwater arena.

### 2.3. Multimodal Communication

Land-based sensor networks have been exploring multimodal communication for years. For example, in [11,12] the authors describe gateway devices that combine short range and long range communication. Similarly Acoustic communication typically dominates the power usage in underwater sensor networks. As networks underwater have very limited recharging capabilities, this challenges the network's ability to communicate collected data. To balance these conflicting needs, we utilize a sensor network platform with underwater acoustic communication, surface level radio communication, and a depth adjustment system to switch between them. Nodes determine if they should surface to communicate by approximating the network energy usage and data latency given the data transmission size.

Just like underwater systems, the in-network modem and gate ways become choke-points.Chen and Ma describe MEMOSEN [4], and demonstrate the effectiveness of mobile multimodal systems in sensor networks. MEMOSEN uses clustering to structure networks. Within a cluster, a low-power radio such as Bluetooth is used to facilitate data transfer. Between clusters and out of the system use a longer-range/higher power device, with designated gateways.

### 2.4. Acoustic and Radio Energy Analysis

In this section, we compute the energy usage of the acoustic and radio modem. Since the radio requires surfacing, we also consider the energy required to move the node to surface. The energy usage numbers are theoretical; however, our computations use realistic numbers that match our empirical energy usage. The acoustic modem has a maximum transmission power of about 10 watts. However, it typically uses a lower power mode that operates at about 5 watts. Recall that the modem uses a decentralized TDMA algorithm. In each 4 second TDMA slot, we can send and receive a 16 byte packet with 11 bytes of payload. Thus we have a throughput of 5.5 bytes per second. This translates to an acoustic power per bit, Pac, of:

$$Pac = 5W/(5.5 * 8bits/sec) = 113.6mJ/bit. \quad (1)$$

The AquaNodes use a 1 watt 900 MHz radio with an RF baud rate of 76800 bits per second. For broadcast mode, the radio transmits each packet 6 times to ensure reception and, additionally, to simulate full-duplex operation, after each packet transmission, it waits for a time period equal to the packet reception time to allow other radios to transmit. This means the true data rate for this radio is closer to:

$$76800/6/2bits/sec = 6400 \text{ bits/sec}. \quad (2)$$

We can then calculate the power per bit using the radio, Prd, as:

$$Prd = 1W/6400 \text{ bits/sec} = 0.16mJ/bit. \quad (3)$$

However, to send using the radio, the node must first rise to the surface using the depth adjustment system. The depth adjustment system uses about 0.6 watts and moves at 2.4m/min. Thus, we need a power per meter, Pw of:

$$Pw = 0.6W/0.04m/sec = 15000mJ/m. \quad (4)$$

The total power, Prw to transmit k bits from a depth of d meters using the radio and depth adjustment system (assuming we return to the same location after) is:

$$Prw = 2dPw + kPr = 2d * 15000mJ + k * 0.16mJ. \quad (5)$$

## III ALGORITHM

In this section we discuss the algorithms we implemented. Our algorithms based on the connectivity matrix defined in 3.2. In short, a logical matrix where true represents a connection, and the connections are determined by the distance between nodes and the range of the active modem. Further, all of the algorithms assume radio range is greater than or equal to acoustic range. This is not a requirement of the environment; it is only a detail of how they were implemented. The final requirement imposed, that is necessary for a successful simulation, is that each node has at least one acoustic neighbour. This automatically guarantees a minimum of one radio neighbour because if two nodes are within acoustic range, they are guaranteed to be within radio range. For this algorithm, the general sequence of events is: select the target node, find shortest cost efficient path, identify the farthest hop within acoustic range in the selected path, issue a rise command, now finds next hops within radio range and issue rise commands and forward the radio message after a short delay. An example of this can be seen in Algorithm 1, which shows the generic process from start to finish.

### 3.1 Min Node Floating Approach

Start Node use the direct weighted matrix to determine the farthest connected neighbour with in radio range and enqueue these nodes until the destination node come with in acoustic range. Now dequeue the queue and send rise command to all these nodes.

**Min Node Floating Algorithm**

```
Initialize
Enter Sn = Start Node
Enter Dn = Destination Node
Enter Ar = acoustic range
Enter Rr = Radio Range
Q = Ø
MNF (G, Sn)
Begin
Nx ←— Sn
While (Dn not with in Ar from Nx)
{
        Find farthest node with in Rr to Nx
        Enqueue(Q , Nx)
        Nx = new node;
}
While (Q ≠ Ø)
{
        Do N  ←— Dequeue (Q)
        Rise N
}

Transfer message using radio modem upto Nx from Sn.
Send drop command to all Floating nodes
Transfer message using Acoustic modem from Nx to Dn.
```

The desired message sent upto the last floating node on the water surface Nx. All rise nodes commands drop down back to its previous position. And in last step the Nx node send message to the destination node Accoustically. Nodes being spaced evenly near the edge of acoustic range would create a best-case topology for this algorithm, as this is the definition of having only one forward-neighbour.

### 3.2 Simulation and Result

For simulation we use MATLAB R2013A. For simulation we take the data as per describe in table 2.

**Table 2. Statistics taken in proposed approach**

| | |
|---|---|
| Acoustic communication cost | 113.6 mj/bit |
| Radio communication cost | 0.16 mj/bit |
| Rising node cost | 15000 mj/meter |
| Range of communication in water | 10 meter |
| Range of communication in air | 20 meter |

Now we consider the effect of data size on energy consumption that communicated between nodes, for this we calculate the energy consumption from dijkstra approach and also from proposed Min Node Floating approach. Fig.1 show the comparison between dijkstra approach and proposed approach that describe when size of data is less than 8 kilobytes then communication cost for dijkstra approach is also less than the proposed approach but when size of data become more than or equal to the 10 kilobytes then dijkstra approach have more communication cost as compare to the proposed approach where as fig.2 show that when data size become more than 10 kilobytes and increasing continuously then there is a wide difference between the communication cost of dijkstra and proposed approach, proposed approach have much lesser cost as compare to the dijkstra.

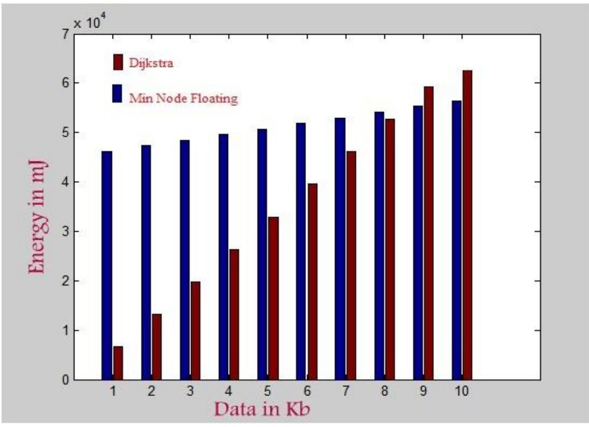


Fig 1.

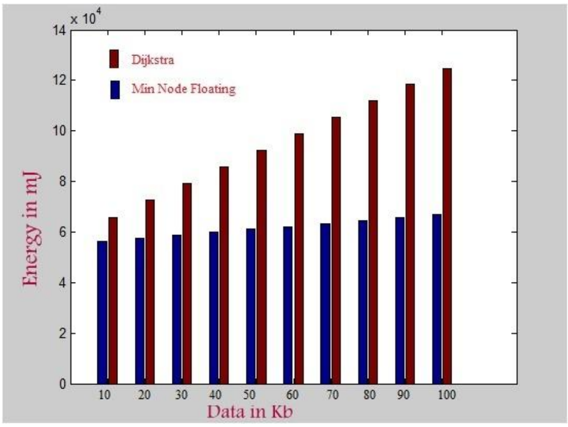


Fig 2.

## IV CONCLUSION

Proposed min node floating algorithm reduced the consumption of energy very efficiently with minimum number of nodes rised, radio communication when nodes are raised to water surface by depth adjustment system and by using acoustic communication when nodes are sub merged in water. Whereas simulation results and comparison of proposed algorithm with the dijkstra show that energy consumption for dijkstra is much higher than proposed algorithm as data size expanded.

## V FUTURE WORK

The work of this paper can be extended in two ways. In first way we can extend the capabilities of simulators. And by implement the whole experiment in a physical underwater environment in other way. Some ways the simulator could be expanded are: allowing node sleep or power loss, implementing the behavior of the AquaNode multiprocessor system (including variable power requirements), and implementing communication interference.

The goal of this paper has been to develop a simulation environment and a proposed algorithms for evaluation. There are many new and exciting approaches to the problems aquatic systems face, and we hope we've made the process of exploring these approaches a little easier. It is critical we properly develop and leverage aquatic technology so we can understand and make use of what the ocean provides.

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