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Receiver Initiated Dynamic Duty Cycle Sheduling Scheme For Underwater Wireless Sensor Networks

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Abstract

This work presents a study about the problem of data gathering in the inhospitable underwater environment. Besides long propagation delays and high error probability, continuous node movement also makes it difficult to manage the routing information during the process of data forwarding. In order to overcome the problem of large propagation delays and unreliable link quality, many algorithms have been proposed and some of them provide good solutions for these issues, yet continuous node movements still need attention. Considering the node mobility as a challenging task, a distributed routing scheme called Hop-by-Hop Dynamic Addressing Based (H2- DAB) routing protocol is proposed where every node in the network will be assigned a routable address quickly and efficiently without any explicit configuration or any dimensional location information. According to our best knowledge, H2-DAB is first addressing based routing approach for underwater wireless sensor networks (UWSNs) and not only has it helped to choose the routing path faster but also efficiently enables a recovery procedure in case of smooth forwarding failure. The proposed scheme provides an option where nodes is able to communicate without any centralized infrastructure, and a mechanism furthermore is available where nodes can come and leave the network without having any serious effect on the rest of the network

Introduction

The ocean is vast for covering around 140 million square miles and more than 70% of the earth surface, and half of the world's population is found within the 100 km of the coastal areas. Not only has it been a major source of nourishment production, but also with time taking a vital role for transportation, presence of natural resources, defensive and adventurous purposes. Even with all its importance to humanity, surprisingly some people know very little about water bodies of the Earth. Only less than 10% of the whole ocean volume has been investigated, while a large area still remains unexplored. With the increasing role of ocean in human life, discovering these largely unexplored areas has gained more importance during the last decades. At one side, traditional approach used for underwater monitoring missions have several drawbacks and at the same time, these inhospitable environments are not feasible for human presence as unpredictable underwater activities, high waterpressure and vast areas are major reasons for unmanned exploration. Due to these reasons, Underwater Wireless Sensor Networks (UWSNs) are lately attracting many researchers, in particular for those working on terrestrial sensornetworks.

Sensor networks used for underwater communications are different in many aspects from traditional wired or even terrestrial sensor networks [1, 2]. Firstly, energy consumptions are different because some important applications require large amount of data, but very infrequently. Secondly, these networks usually work on a common task instead of representing independent users. The ultimate goal is to maximize the throughput rather than fairness among the nodes. Thirdly, for these networks, there is an important relationship among the link distance, number of hops and reliability.

Due to these reasons, UWSNs provide a platform that supports to review the existing structure of traditional communication protocols. The current research in UWSNs aims to meet the above criterion by introducing new design concepts, developing or improving existing protocols and building new applications.

Research Objectives

The main objective of this thesis is to design and implement a dynamic addressing based routing protocol for underwater environment where scalability and resource efficiency becomes an essential requirement of the network. From literature review, it is proved that UWSNs are with some specific characteristics that are not found in the terrestrial sensor networks.

In our research work, the following points shall be investigated.

- Porting the common information and tools available in traditional WSN like basic routing ideas and trying to implement them for Underwater Wireless Sensor Networks
- Highlighting the future challenges that can be possible due to a new underwater volatileenvironment.
- Delay sensitive and tolerant applications here will be separate mechanisms in order to handle the connectivity issues. For delay tolerant applications, a mechanism to handle the loss of connectivity, instead of provoking immediate retransmissions will bedeveloped.
- According to different conditions and applications, packet priorities will be dynamically calculated by adjusting their weights, so resource consumptions can be considereddduringthedataforwardingaccordingtothepacketsofdifferentpriorities.
- By considering all these issues, algorithms; those give better routing result as well as provide strict or loose latency bounds for both delay tolerant and time critical applications will bedeveloped.

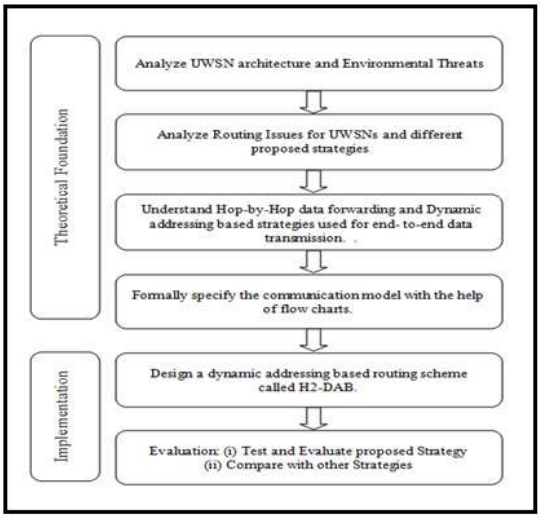


Fig1: Research methods

Problem Setting and Network Architecture

During this research, the application of underwater oil/gas field monitoring is considered. For this purpose, underwater sensor nodes are deployed in the whole monitoring area to collect the information from the surroundings and report to the surface buoys. As already mentioned, our protocol is based on the multisink architecture, which is very helpful to increase not only the delivery ratios but also the network life by decreasing the energy consumption of the nodes around the sink. Surface sinks are equipped with radio and acoustic modems, where RF modems will be used to communicate with each other and with the final data processing centre. Acoustic modems are used to communicate with the sensor nodes deployed at different depth levels with the buoyancy control. In horizontal directions, they can freely move with the water currents but in vertical one, a node may have small variations, which can be negligible.

By doing so, nodes will form layers from the surface to the bottom. The numbers of layers depend on the depth of the monitoring area and the communication range of the sensor nodes. The average depth of oceans is around 2.5km to 3km, and acoustic communication range of sensor nodes is not preferred more than 1 km. However, by considering every layer at 500 meter, then maximum of 5 to 7 layers are required to deliver the data packets from bottom to surface at the average ocean depths. It is important to note that the performance of our protocol not depend on the number of layers. The proposed algorithm can easily support more layers, but if we increase the number of layers, the cost of the network will increase as more nodes are required for the same depth.

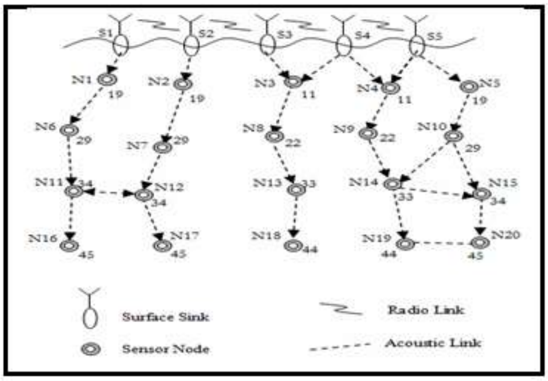


Fig2: Assigning HopIDswith the help of hello packets

Energy Consumption with Static Nodes (Best Case)

For static scenario, every node will not only send only one Inquiry Request but also get single Inquiry Reply. Following that, NodeIDof replying node is saved in the routing table and will be used as a next hop for all the remaining data packets.
For the first time, energy consumption for a single data packet from any lower layer to next upper layeris
$E_d=2e_c+e_d$(1)

Where, “$e_c + e_d$” is the consumption from current layer which has data packet. At first it sends an Inquiry Request and then forwards the data packet after receiving the Inquiry Reply. The remaining “e_c” meanwhile is the consumption from upper layer when a node replies with the Inquiry Reply. First we consider the case, when data packet is generated at a node in the first layer and it forwards directly to the sink “S”. After that, data packet is similarly generated at the second layer and forwarded towards the sink through the first layer and so on. The effect of energy consumption at each layer can be represented by the followingequations.

$E_{1\to S} = (e_c + e_d)$

$E_{2\to S} = (2e_c + 2e_d) + (e_c + e_d)$

$E_{3\to S} = (2e_c + 3e_d) + (2e_c + 2e_d)+ (e_c + e_d)$

$$\vdots$$

$E_{m-1\to S} = (2e_c+ (m-1)e_d) + (2e_c+ (m-2)e_d) + ... +(2e_c + 2e_d) + (e_c + e_d)$

$E_{m\to S} = (2e_c+m.e_d)+(2ec+(m-1)e_d)+...+(2e_c + 2e_d) + (e_c+e_d)$(2)

Equation (2) shows how the upper layers are affected when one node at every layer generates a data packet and total m data packets are forwarded towards the sink. It is clear that layer 1 processes all m data packets and due to that it faces maximum energy consumption ($2e_c + m.e_d$) than any of the other layer. Layer m has the least energy consumption ($e_c + e_d$) as it processes only one data packet. Now, when k data packets are generated on the same node of each layer, we can represent equation (4) as follows.

$$E_{m.k\rightarrow S}=(2e_c+k.m.e_d)+(2e_c+k.(m-1)e_d)+\ldots+(2e_c+k.2e_d)+(e_c+k.e_d) \qquad (3)$$

With the above equation, energy consumption at layer i can be calculated as it is to process its own generated data packets as well as energy to forward the data packets of all the lowerlayers.

$$E_i= (m-i)k.e_d + k.e_d + 2e_c$$

where i < m We use ρ to denote $k.e_d$. Now we can write,

$$E_i= (m-i)\ \rho + \rho+2e_c \qquad = (m-i + 1)\ \rho + 2e_c$$

Life time of layer i can be calculatedas

$$T_i=n.\varepsilon/(m - i + 1)\ \rho + 2ec$$

$$Ti/n=\frac{\varepsilon}{m - i + 1)\ \rho + 2\varepsilon}$$

Algorithm for Assigning theHopIDs

```
Hello packets (hp) Broadcasts From all Sinks with HopID "$N_{00}$" & Max Hop Count = 9
//Hello packet received
    Get Received New-HopID "$N_{rs}$" from hp
    Get Own-HopID "$N_{pq}$"
    If r = 0 &&$Sk_{ID}$ (p) != $Sk_{ID}$ (r)    // Existing sink ID != Receiving sink
    ID Or      r != 0 && r < p <= s
Then
        q   p   ←
        p   r+1 ←
        If r & s <p Then
            p   r+1   ←
            q   s+1   ←
        If r >= p   && s < q        Then
            q   r+1     ←
        Else
            Max Hop Count = 1       // In order to stop further broadcast
        End If
    End If
```

```
End If
Max. Hop Count - 1
If   Max Hop Count > 0 Then
    Update   hp $\leftarrow$ OwnHopID
    Broadcast hp further
Else
    No further broadcast for this hp
End If
```

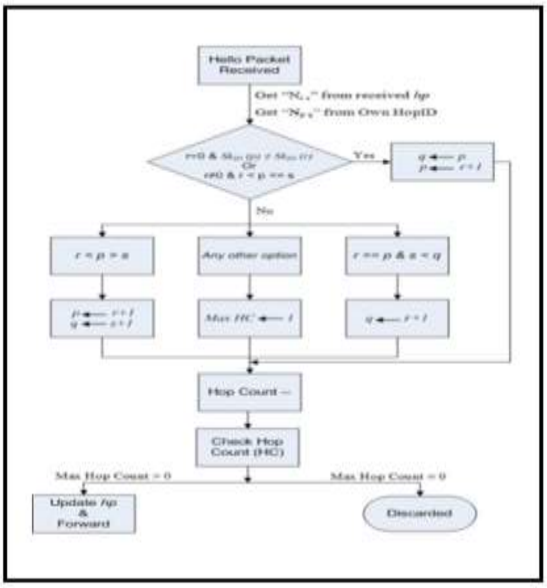


Fig 3: Flow Diagram for Assigning theHopIDs

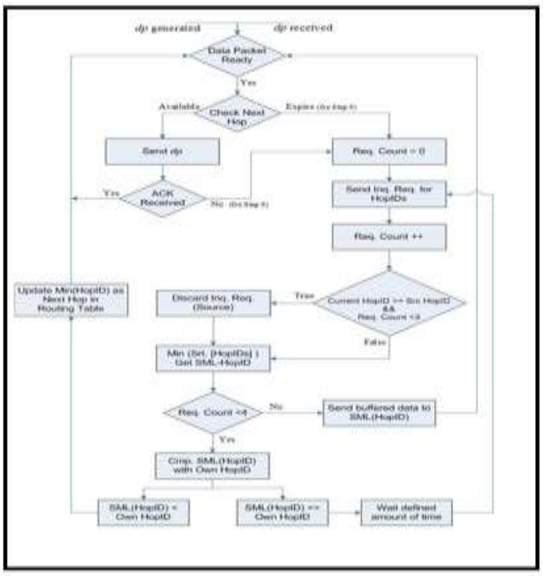


Fig4: Flow Diagram for Forwarding the DataPacket

Result

we evaluate H2-DAB with different parameters including node mobility, different number of courier nodes, variations in interval life and with different offered loads.
The data delivery ratios at different speed of node movements; three Courier nodes were used during the simulation setup. As shown in the figure, the data delivery ratios are 100% with the suggested number of nodes inthe network. These delivery ratios are not seriously affected if the node density starts to decrease, we can still achieve around 95% delivery ratio if 25-35% nodes are not available.

If we look at the delivery ratios in the sparse areas, where 50% nodes are not available, we can still receive around 85% data packets at the average node movements.

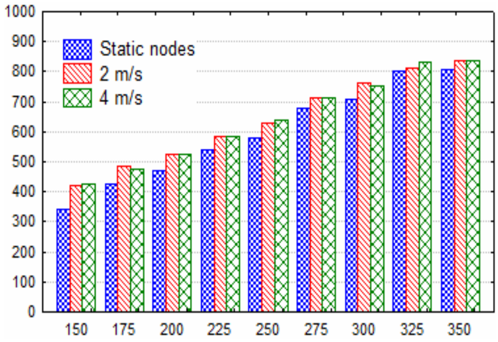


Fig6: Effect of node movements on H2-DAB (end-to-end delay)

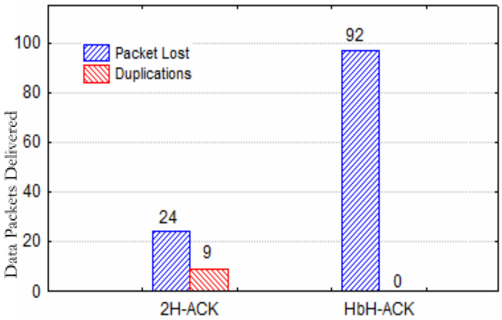
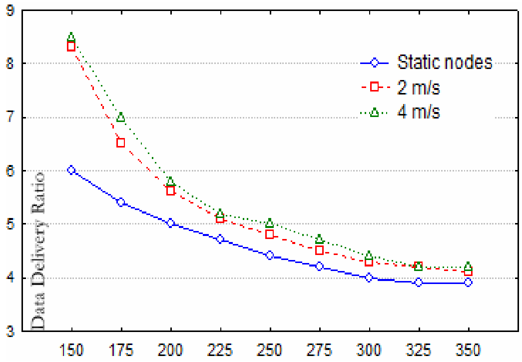


Fig7:2H-ACK vsHbH-ACK (packet losses and duplications)



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