Algorithms for Power-Efficient Data Acquisition in Underwater Sensor Networks

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Abstract: - Approaches that have already been developed for terrestrial sensor networks cannot be used for Underwater Sensor Networks (UWSN) because of certain features of acoustic communication [2,3]. Therefore, we propose an architecture for UWSN that aims to deliver the information from under water to the surface and then to the control center from there. We formulate the mechanism using a grid pattern of local sinks on the sea surface and randomly moving sensors, forming a wireless underwater ad-hoc network under the sea surface. This design concentrates on the reception of information. Although reliability is achieved through the redundancy of data, our work is aimed at controlling the congestion as well. The mechanism has been made self-adjusting so as to achieve robustness. A solution for the important problem of power management has also been proposed. The primary goal of this system is to make oil discovery process under water easier.

Key-Words: - Underwater sensor networks, Power-Efficiency, Simulation.

1 Introduction

Today, the rapidly growing needs for fuel [4] motivate us for the discovery of new resources. As we all know, approximately 70% of the Earth is covered with bodies of water which, in turn, are very vast homes of many resources that are helpful in meeting the day to day needs. Searching for oil under water is an important task today [4]. Carrying out the search processes under water is not that easy, because of certain features of water that, in turn, makes it very difficult to employ the already designed search methods for terrestrial use. These features include the variations in the levels of salinity, temperature and pressure [2] under the surface of water. In addition, these factors also affect under water wave propagation.

Wave communication depends on the frequency being used. The attenuation in sea water increases with frequency [1,5]. More frequency means more attenuation. Hence, for underwater communication, we cannot use radio waves that have very high frequencies. Sound has superior propagation characteristics in water [5], so, a suitable mode for underwater communication is the use of acoustic channels for communication [2]. Still, to minimize the effect of attenuation and healthy reception of signals, transmissions need to be carried out at higher powers. Moreover, the velocity of signal propagation in underwater acoustic channels is approximately equal to 1500 ms^{-1} [2], which is five orders of magnitude smaller than the velocity of radio propagation in air, i.e., 3x108 ms^{-1}. Hence, a large propagation delay is induced in underwater acoustic communication [8].

Apart from all these, the underwater acoustic link is temporal in nature and nodes are mobile, which means frequent loss of connection among the nodes undergoing interactions. Also, this link offers a very less bandwidth for communication [5,6], which results in very less information transfer during communication. This, in turn, accounts for lesser efficiency of UWSN. Underwater currents, ambient noise of marine life, volcanic eruptions, harbour / on-shore activities and other minor factors also affect the signals and may distort them [7,8,9]. These effects are inevitable to some extent.

The sensor nodes in a UWSN work on batteries.

Also signal transmission and forwarding consumes a certain percentage of power from the battery [5]. So, these networks must be power-efficient. Then only the overall life of the network would be significant. In this paper, we propose the Power-Aware Data Acquisition technique, a multi-hop ad hoc routing and in-network processing protocol that utilizes the power available with the sensors significantly and incorporates recovery protocol in case of network failure. But these features are also subjected to hardware implementations. So, they should not be considered solely on the basis of simulations.

2 Proposed Algorithms

The entire process is carried out using two algorithms. The first one is the *HOP-COUNT Algorithm* and the second one is the *POWER MANAGEMENT Algorithm*.

From the implementation point of view, a global procedure, which coordinates these two algorithms, must be in place. This procedure has been named as the *SENSING Algorithm*.

2.1 Sensing Algorithm

This algorithm is used to depict how each node would sense other nodes and then their actions on the detection of oil. This algorithm does not use any acknowledgement for maintaining the reliability of the data sent.

Step 1: Initially local sinks start the HOP-COUNT algorithm. This makes hop-count tables for each sensor, which will be used as routing tables for sending the data packets.

Step 2: Whenever there is change in luminance or the luminance level reaches the expected value, the sensor node will enter into active mode and initiate the transfer of data.

Step 3: On activation, the sensor node will try to send data to all reachable sinks by multicasting data packets to their previous hops one step towards those sinks. The node will not wait for any acknowledgement. It will just again enter the sensing mode and wait for the next change in luminance level.

Step 4: The receiving node then checks for the Initial Time Stamp and the Source Node ID on the received data packet. If any of the two is different from the previously received data, it will accept it. Otherwise, it will reject it. The receiver node will try to transfer the packet in the same fashion, in order to forward it to any of the local sinks on the surface.

Step 5: If the sensor node receives a data packet with its own ID as the Source Node ID, it will reject it just to minimize the circulation of packets in the network.

Step 6: The node will drop the received packet after transmitting it to all previous hops.

Step 7: The sensor nodes carry out the POWER MANAGEMENT algorithm in parallel when they are in active mode. That is, they try to manage their own battery power along with every transmission or after a fixed duration of time.

Step 8: After some predefined time, the sink node again starts the HOP-COUNT algorithm and all the sensing nodes redefine their hop-count tables (later to be used as routing tables). This will insure that nodes damaged or lost are no longer a part of the network. It will also ensure the existence of the network, despite the effect of water currents, and all sensor nodes will have recent information about the nodes in range. This takes care of the random localization of nodes.

2.2 Hop-Count Algorithm

This algorithm is used in the initialization stage of the network, at regular intervals and also on-requirement. This algorithm is used to generate or update hop-count tables, which are further used for the routing of data packets.

```
Initialize the entry for each local sink at each sensor node with
STORED_COUNT = 2048;
PREVIOUS_HOP = NULL;

if (HOP-COUNT-UPDATE message is received by sensor node for ith sink)
{
  for ith entry in the hop-count table of that sensor node
  {
   if (SEQUENCE_NUMBER > STORED_SEQUENCE_NUMBER )
    if (RECEIVED_HOP_COUNT < STORED_HOP_COUNT)
    {
      STORED_HOP_COUNT = RECEIVED_HOP_COUNT;
      PREVIOUS_HOP = Node ID of this last node which sent data packet;
      Create a new message of this form
      [ ith sink, ID of this node, STORED_COUNT++ ]
      and unicast or multicast it to nearest neighbours.
    }
  }
}
```

Fig. 1: Hop-Count Algorithm

2.2. Power Management Algorithm

Sensors are deployed at various levels under the water surface, by making use of the fish-bladders available with the sensors. Some sensors are placed at the bottom, some on the surface and some in between. At regular intervals of time, the sensors that are not at bottom start moving downwards depending on the P'k (i.e., the previously estimated threshold power for each level, while moving downwards) by one level at a time. The THRESHOLD_POWER is defined in such a way that the sensors stay at the bottom for some feasible amount of time. After that when their power level drops below that threshold, they start moving upwards depending on the P''k (previously estimated threshold power for each level while moving upwards) value.

```
Initialize these variables
for ( each level k )
{
   P'k = x;
   P''k = y;
}
THRESHOLD_POWER = z;

for each level 'j'
{
   if ( transmission is carried out by the sensor )
   {
     It will update its power, Pj
   }
   if ( Pj > THRESHOLD_POWER )
   {
     while ( Pj <= P'k ) for k = j
     {
       Move downwards with deflation of fish bladder
     }
   }
   else
   {
     while (Pj <= P''k) for k = j
     {
       Move upwards with inflation of fish bladder and update Pj
     }
   }
}
```

Fig. 2: Power Management Algorithm

3 The UWSIM Simulator

A new simulator, UWSim was developed. Though a large numbers of simulators exist commercially, no popular ones exist that are purely based on the UWSN network conditions. The widely available commercial general network simulators properly simulate the ground-based MANETs. But they do not consider the factors that affect the underwater communication. The important reasons for developing this new simulator are as follows:

- Most simulators were based on ground MANETs. These simulators use radio frequency transmission for establishing the networks. Since radio networks hardly work in the underwater scenarios, the need for developing a simulator, which simulates the acoustic network, exists.
- All simulators are based on either the proactive or the reactive routing protocols such as AODV and DSR. Since our solution approach is somewhat different from the existing protocols, there was a need to have such support.
- The various characteristics of underwater networks such as low bandwidth, need for high frequency, effect of salinity and temperature with depth have to be considered for simulation of such network. Hence, these characteristics were embedded in the simulator.

Hence, a new simulator was developed. UWSim is currently custom-designed for our own algorithm, with lots of scope left for future expansions in the simulator.

4 Preliminary Results

In this Section, we report the preliminary set of results obtained. The dimensions of data set taken below are of the following units: length, breadth, depth, sinks range, sensor range are in meters; frequency in KHz; Salinity in parts per thousand; and Temperature in ^{0}C.

In our preliminary studies, we considered the metric, *Packet-Delivery Ratio* (*PDR*), which is defined below. However, we are currently investigating other metrics such as the *Average-End-to-End Delay*, *Connection Reliability* and *Efficiency*.

PDR: It is the ratio of packets received by sinks to the total number of packets generated in the network in sending single information.

$$\text{PDR} = \frac{\text{Packets Received by Sinks}}{\text{Packets generated through the network}}$$

The more the value of the PDR, the better is the reliability of the network.

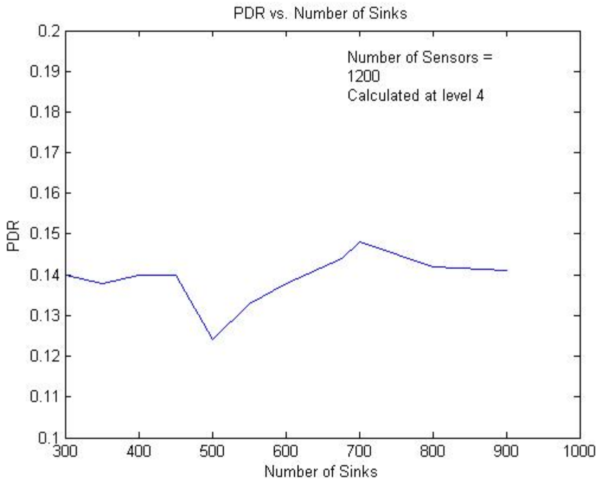

Fig. 3 – PDR vs. Number of Sinks

The plot in Fig. 3 shows that PDR remains constant for sinks greater than the optimum number of sinks. On decreasing the number of sinks, it decreases, and then again, it becomes nearly constant.

5 Conclusion

We conclude from the preliminary set of results that the proposed set of algorithms works efficiently for the parameter we considered. Since the amount of available power is limited with the sensors, the POWER-MANAGEMENT algorithm comes handy, and can help each sensor to utilize power efficiently in sensing, without failing the network due to the end of battery.

This is a work-in-progress paper. We are currently investigating the problem by considering other performance parameters and extending the UWSim simulator.

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