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An efficient Dynamic Addressing based routing protocol for Underwater Wireless Sensor Networks

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ABSTRACT

Underwater Wireless Sensor Networks (UWSNs) are different in many aspects as compared to terrestrial sensor networks. Other than long propagation delays and high error probability, continuous node movement makes it hard to manage the location information of sensor nodes. Determining the location of every node is a major issue as nodes can move continuously with the water currents. In order to handle 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, but continuous node movements still need attention. In order to handle the problem of node mobility, we proposed a Hop-by-Hop Dynamic Addressing Based (H2-DAB) routing protocol, where every node in the network will be assigned a routable address in a quick and efficient way without requiring an explicit configuration or any dimensional location information. It helps to provide an option where nodes can communicate without any centralized infrastructure, also a mechanism is available where nodes can come and leave the network without having any serious effect on the rest of the network. Simulation results show that H2-DAB can manage easily during the quick routing changes where node movements are very frequent yet require little or no overhead in order to complete its tasks.

1. Introduction

A scalable Underwater Wireless Sensor Network (UWSN) provides a promising solution for discovering the aqueous environment efficiently and observing such locations for different applications which operates under many important constraints. On one hand, these environments are not feasible for human presence as unpredictable underwater activities, high water pressure and vast areas of water are major reasons for un-manned exploration [1,2]. At the same time, localized exploration is better than remote for getting more precise results, as remote sensing technologies may not be able to find appropriate knowledge about the events that happen in unstable underwater environment.

In fact, UWSNs share many properties with terrestrial sensor networks such as the large number of nodes and energy issues, still these are different in many aspects from the terrestrial sensor technology. Firstly, radio communications are not suitable for deep water, so we have to replace this with the acoustic communications. Due to this replacement, available propagation speed is shifted from the speed of light to the speed of sound. Although, acoustic sound travels faster (four times) and longer in water than in air but yet five order of magnitude slower than electromagnetic waves. Secondly, most of the times, sensor nodes are considered as static but underwater sensor nodes can move up to 1–3 m/sec due to different underwater activities [3]. Thirdly, consumption of energy is different for both types of networks, as underwater nodes are larger in size so they consume more power and the replacement of the nodes or even batteries is not so easy. Low data rates due to limited bandwidths are also a major problem for such type of networks. The routing protocols that require higher bandwidths, results in large end-to-end delays and are not suitable for these environments. Although UWSN communications are divided into different categories in terms of bandwidth and ranges, acoustic signals can work even for 5 km, but data rates at such ranges are very small and not suitable for real time communications. In short, it is hard to increase the data rate from 40 kb/s with a range of 1 km.

2. Related work

It is a challenging task to find and maintain the routes for dynamic underwater environments with energy constraint and sudden topology changes due to some node failures. For these circumstances, recently many routing schemes have been proposed for UWSNs and among these, most of them require or assume special network setups and generally can be divided in two categories [4]. First, those required special network setups and extra hardware like [5–11]. All these protocols require extraordinary

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hardware setup and multiple types of nodes like sensor nodes are equipped with pressure or depth sensor, many nodes are anchored at different depths in throughout the observing area and etc. Arrangements like these are not easily possible for long term applications; in addition when we are interested in large areas then cost become a major issue. Second category is of geographical based routing schemes, those require full dimensional location information of the network. For the sake of simplicity, most of the protocols of this type assume that every node in the network already knows its own location and location of final destination. Assumptions like these are not so simple because in order to get the localization information in UWSNs, we need some extra location aware method, which is another research issue left to be solved. Some important schemes belong to this category are [12–17]. For comparison purpose, a short summary of some routing schemes is described in Table 1.

Contributions: Although, some impressive hop based routing techniques like [21,22] are available in literature review but it is not easy to implement them for UWSNs due to different environmental characteristics. In this paper, we proposed a novel routing protocol called **Hop-by-Hop Dynamic Addressing Based (H2-DAB)** for critical underwater monitoring missions. H2-DAB is scalable and energy efficient and it will use multi-sink architecture. Surface buoys will be used to collect the data at the surface and some nodes will be anchored at the bottom. Remaining nodes will be deployed at different levels from surface to bottom. Nodes near the surface sinks will have smaller addresses and these addresses will increase as the nodes go down towards the bottom. These dynamic addresses will be assigned with the help of hello packets; those are generated by the surface sinks. Any node which collects the information will try to deliver it towards the upper layer nodes in a greedily fashion. Packets that reach any one of the sinks will be considered as delivered successfully to the final destination as these buoys have the luxury of radio communications, where they can communicate with each other at higher bandwidths and lower propagation delays. For better resource consumption and to increase the reliability, we will use some special nodes called Courier nodes. These Courier nodes will collect the data packets from lower layer nodes, especially from the nodes anchored at the bottom and after collecting will deliver these packets directly to the surface sinks.

The main advantages of H2-DAB are as follows:

I. Node movements with water currents can be handled easily.
II. No need to maintain complex routing tables.
III. It does not require any location information.
IV. It will take the advantage of multi-sink architecture (For single sink, nodes around the sink entertain large amount of data packets, not only it can lead to the problem of congestions and data losses but also these nodes can die early due to frequent energy consumption).

Table 1
Short summary of protocols which require special network setups.

Algorithm	Requirement/assumption (s)
DBR [5]	Every node should be equipped with a depth sensor.
Localization scheme [11]	(i) Special DET nodes are required, equipped with an elevator. (ii) Some nodes require anchoring at different depths and locations in whole area.
Localization For USN [18]	(i) All nodes must be clocked synchronized. (ii) GPS communication and Time of Arrival (ToA) method required.
VBF [12]	Assumed that full dimensional location information of whole network is available.
FBR [13]	It is assumed that every node knows its own location.
REBAR [14]	It is assumed that every node knows its own location and location of sink.
SBR-DLP [15]	Every node knows its own location information and pre-planned movement of destination.
DFR [16]	All nodes know not only their own location but the location of one hop neighbors and location of sink as well.
LASR [19]	(i) Accurate timing required for synchronization and range estimation. (ii) Network should consist of small number of nodes; adding new nodes will expand the protocol header overhead.
Multi-path virtual sink [20]	(i) Two special types of nodes are required (ii) Local sinks at different depths and locations are connected with each other via high speed links (RF link or Optical Fibre).
UW-HSN [9]	(i) Every node should be equipped with both, radio and acoustic modems. (ii) Every node uses a mechanical module, to emerge and submerge operation.
Resilient routing [6]	(i) Every sensor node is connected with a long wire which is anchored at the bottom. (ii) Sensor should have an electronically controlled engine to adjust the length of the wire.

3. Problem statement and network architecture

We are considering the application of underwater oil/gas field monitoring, for this purpose sensor nodes are deployed in the whole monitoring area in order to collect the information from the surroundings. As already mentioned, our protocol based on the multi-sink architecture, which not only very helpful for increasing the delivery ratios but also increase 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 to communicate with the final data processing centre, while acoustic modems are used to communicate with the sensor nodes. The sensor nodes are deployed at different depth levels with the buoyancy control [8,23,24]. In horizontal directions, they can move freely with the water currents but vertically a node may have small variations, which can be negligible [3,23].

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 2.5–3 km [25,26], and acoustic communication range of sensor nodes is not preferred more than 1 km. However, if we consider every layer at 500 m, then maximum of 5–7 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 does not depend on the number of layers. The proposed algorithm can support easily more layers, but if we increase the number of layers, it will increase the cost of the network as more nodes are required for the same depth. If we decrease these layers as acoustic communications support up to the range of 5 km but it is not preferred as long distance communications drain more energy [13,27]. In order to save energy and extend the network life time, we define the acoustic communication range of sensor nodes up to 800 m. It is found that acoustic communications are considered short range up to the distance of 1 km and are able to provide a bandwidth of 20–30 kHz [28,29]. Although, in special cases, we can increase this [27,30], but during normal cases there is no need to increase more than this suggested range.

In many applications we are more interested to collect data from the nodes anchored at the bottom like oil/gas field monitoring; in such applications events occur more frequently at the bottom. In order to collect this frequent data from the lower layers in a fast way with the involvement of fewer nodes, we prefer the use of Courier nodes. These special nodes can sense as well as can receive