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International Journal of Innovative Research in Technology, Science & Engineering (IJIRTSE)
ISSN: 2395-5619, Volume – 4, Issue – 4. June 2018

Joint Routing and Energy Management in Underwater Acoustic Sensor Networks

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ABSTRACT-

Fundamental differences between underwater acoustic propagation and terrestrial radio propagation may impose the design of new networking protocols and management schemes. . Indeed, energy management is one of the major concerns in UW-ASNs due to the limited energy budget of the underwater sensor nodes. In this paper, the unique characteristics of the underwater channel. The main contribution of this study is an in-depth analysis of the impact of these unique underwater characteristics on balancing the energy consumption among all underwater sensors. In particular, we propose a balanced routing strategy along with the associated deployment pattern that meticulously determines the load weight for each possible next hop, that leads to fair energy consumption among all underwater sensors. Consequently , the energy holes problem is overcome and hence the network lifetime is improved.

Index Terms—UnderWater Acoustic Sensor Networks, routing, load management, energy management, performance analysis.

I. INTRODUCTION

UnderWater Acoustic Sensor Networks (UW-ASNs) are gaining a remarkable momentum within the research community. Acoustic communication is deemed to be the enabling technology for underwater networks.Acoustic modems are the current technology of choice for underwater communications. . We strive for deriving the optimal load weight for each possible power level that leads to fair energy consumption among all sensors in the network and hence the sink-hole problem is overcome. That being said, it is worth pointing out that our proposed routing protocol is more suitable for collision-free MAC protocols. Our contributions can be summarized as follows. First, we propose a designed deployment pattern for UW-ASNs aimed at balancing the energy consumption and hence an improved overall energy management. Second, based on the proposed deployment, we prove that we can evenly distribute the transmission load among underwater sensors with constant data reporting provided that sensors adjust their transmission powers when they send or forward sensed data. . On the other hand, increasing n raises the energy consumption since the farthest coronas may be reached. Consequently, in such scenario, these surface sensors that are bottom anchored have a complete knowledge of their geographical position at deployment time. The width of each corona is at most dtx−max, the maximum transmission .In order to approach the uniform energy depletion, sensors are placed in a circular sensor field of radius R centered at the sink. The sensor field is virtually partitioned into disjoint concentric sets termed coronas of constant width r. optimization problem that leads to an even energy depletion among all sensors.

A. Routing in UW-ASNs

Geographical routing protocols seem appropriate for the underwater environment, where manually anchored nodes have knowledge of their coordinates at deployment time, and mobile nodes (such as AUVs) have local navigation systems. Several geographical routing protocols, especially devised for underwater channel have been proposed. In the design of minimum energy routing protocols especially designed for the underwater environment is evaluated. The authors in prove that, depending on the modem per- formance, in dense networks there is an optimal number of hops beyond which the system performance, especially in terms of energy consumption, does not improve. . In a new geographical routing strategy for underwater acoustic networks is introduced and joined with power control. The main contribution of this routing scheme called FBR is to dynamically establish routes on demand without damaging the network performance. In the authors were mainly interested in providing a reliable routing solution especially dedicated for time-critical applications in underwater acoustic networks.

B. Energy Sink-hole problem

The energy sink-hole was originally addressed by Guo et al. in [3]. They proposed an energy-balanced transmission scheme that adjusts the ratio between direct transmission to the sink and next-hop transmission. Accordingly, sensor nodes are deployed in a circular disk around the sink. Each node can send a percentage of data directly to the sink and While VTRP assumes that the sink is static, in [4] the proposed protocol considers sink mobility and energy hetero geneity among sensor nodes in order to overcome the sink-hole problem. Different from the contributions described in this section, in this paper, we present a routing solution dedicated for a specific underwater acoustic network deployment, which overcomes the energy holes problem by achieving a fair load distribution, balanced energy consumption, and better overall network management.

II. MODEL AND PROBLEM DEFINITION

A. Time-varying underwater channel

1) The channel gain*:* In [6], an exhaustive mathematical analysis was conducted to describe the time-varying channel gain in underwater environment by taking into account most of the physical features of acoustic propagation such as frequency-dependent attenuation, the bottom surface re- flections as well as the effects of inevitable random local displacements and its induced Doppler effect.

2) Power Allocation: In a time-varying channel, the power allocation can be either adaptive or invariant. In the latter case, where no power control mechanism is applied a fixed large margin is to be introduced to ensure that the SNR remains above a given threshold SNR0, regardless of the channel conditions. However, for energy efficiency reasons, the transmit power consumption can be minimized if the transmitter has at its disposal some knowledge of the channel gain as stated in 9.

3) Probability of successful packet reception: In our work, in order to further take into account the time-variability of the underwater acoustic channel, we introduce a success probabil- ity P^{i} over a link (i, j) which represents the probability of a successful reception by a node j for a transmission initiated
by i using a transmission power $\hat{P}_T$ (i,j) over a bandwidth B.In fact, a packet reception is considered successful by sensor for a communication initiated by i during the time period.

B.. Network and Energy model

The proposed deployment strategy considers a 2- dimensional shallow underwater sensor network. A set of sensors is anchored to the ocean bottom and endowed with a quite long rope along with a floating buoy to push the sensor towards the surface. Indeed, the buoy can be inflated by a pump in order to push the sensor towards the ocean surface. Note that in this work, we assume that the sensors will be all the time attached to their anchors through the cable which will severely restrict their displacement. Consequently, in such scenario, these surface sensors that are bottom anchored have a complete knowledge of their geographical position at deployment time. It is worth pointing out that our proposed deployment architecture targets especially shallow water which makes the deployment cost re

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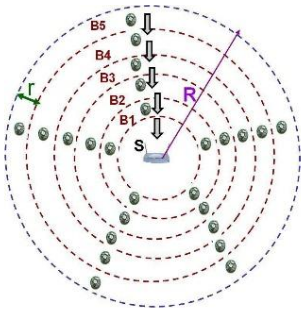


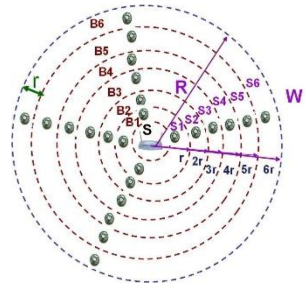


Fig.1. Underwater Acoustic sensor network mod Fig 2: A Wedge W and the associated secxtor

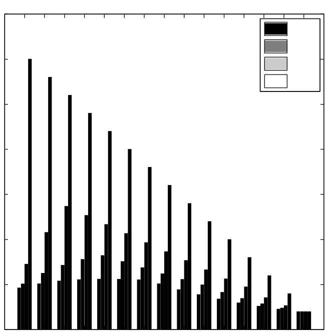
For example, in Fig. 1, K = 5, hence the sensor field is partitioned into five coronas B1, B2, B3, B4 and B5.In the remainder of this paper, we consider a continuous reporting sensor application where the average number of re- ports generated per unit of time by each sensor node is denoted by A. In fact, since in underwater environment, the deployment is generally quite sparse, the energy depletion due to overhearing can be neglected. More precisely, the energy spent in transmitting one packet of length Pl bits over a distance d between two nodes i and j is given by Etx (d) = PˆT (i,j) × Tˆtx(i,j) S1, S2, ..., SK by its intersection with K concentric circles, centered at the sink, and of monotonically increasing radius r, 2r, 3r, ..., Kr, as shown in Fig. 3. Each sector contains exactly one sensor which has to forward the cumulative traffic coming from its predecessors to one of its possible successors. Each sensor specifically in our study we assume that capable of adjusting its transmission power in order to send the appropriate fractions of packet load to one of its possible successors within its maximum transmission range dtx−max. More details are given in the next section.

III. ENERGY MANAGEMENT :

It is easy to show that the total number of paths that may involve a specific node in a given wedge W and in corona Bi includes all possible paths in W except those originating in one of the coronas B1, B2, ..

$$n = \left[\frac{dtx-ma}{t} \right]$$

Fig. 4. In fact, shows the energy consumption for each sensor in the corresponding corona. Accordingly, a 92% of energy saving is achieved at corona 1 when n = 5. It is worth



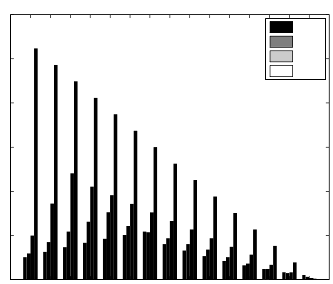


Fig.4.Energyconsumptionpercorona Fig.5.Packet load distribution.

The packet load distribution is shown in fig.5. Note that, adopting a nominal communication range based data forwarding with dtx−max = r (i.e. n = 1) leads to a total accumulated traffic of 1.2 packet/s at sensors in corona 1. This amount of accumulated traffic at corona 1 is highly decreased (less than 0.29 packet/s) with our balanced routing solution when n = 3, a further decrease is achieved with n = 5 and a further gain with n = 7 compared to nominal based data forwarding.

IV-Conclusion

In underwater environment, where solar energy cannot be exploited, operating on energy constrained underwater sensors imposes the design of energy-efficient protocols. These protocols should sensors imposes the design of energy-efficient protocols. These protocols should be carefully designed in order to deal with the dramatically different propagation characteristics of underwater acoustic signals, such as high attenuation and bandwidth- limited channel. For these reasons, UW-ASNs require protocols that make judicious use of the limited battery budget while taking into account the unique features of the underwater channel. To this end, we proposed in this paper a routing strategy that leads to an even energy depletion among all sensors in the network and consequently an improved network lifespan. with the associated transmission power and associated load weight that lead to fair energy consump- tion and hence the energy sink-hole problem is overcome. To do so, we developed a comprehensive analytical model that iteratively derives for each source sensor the appropriate load weight along with the associated transmission power. Analytical results show that significant lifespan improvement is achieved by our balanced routing scheme compared to the nominal communication range based data forwarding.

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