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A High-throughput routing metric for multi-hop Underwater Acoustic Networks ☆

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ABSTRACT

In most wireless network architectures, a routing metric plays an important role for a routing protocol to select suitable paths (or, links) for communications. An inefficient routing metric may increase overall transmission cost per packet by selecting *lossy* links and thereby may lead to poor throughput. Underwater Acoustic Networks (UANs), where most of the nodes operate on battery power, prefer topology-based routing metrics over active probing based routing metrics. Considering this fact, in this paper, we investigate the performance of various topology-based routing metrics over UAN-architecture. We then apply the acquired knowledge to design a new routing metric called Cubic Min to Avg Signal-to-Noise Ratio (CMAS), which is capable of selecting high-throughput links. We evaluate the performance of the proposed metric with other available topology-based routing metrics in underwater scenario. Simulation results demonstrate that the proposed metric attains significantly higher throughput than that of the other compared metrics.

1. Introduction

In the recent years, underwater acoustic communication has received immense attention from the researchers, industries, and various militaries due to its current and future applications, like oceanography, pollution monitoring, offshore exploration, disaster prevention, navigation assistance, monitoring, coastal patrol and surveillance, etc. [1,2]. These seasonable applications are encouraging people from different corners of the globe to invest their valuable efforts in the development of this emerging field of communication. Unlike any terrestrial wireless network, acoustic signals are preferred in Underwater Acoustic Networks (UANs) over electro-magnetic or light signals due to large transmission range. However, since the transmission speed of an acoustic signal is very limited which is several magnitudes lower than electro-magnetic signals, UANs experience higher propagation delay. Moreover, an underwater channel faces higher bit error rate due to multi-path, fading, formation of shadow zones, and refractive properties of the sound channel [2]. Furthermore, limited bandwidth, limited energy and impact of the environment over channel make underwater communication more challenging than its other wired or wireless network counterparts. In such a challenging environment, selection of a suitable high throughput routing metric plays an important role in multi-hop communication. Fig. 1 shows a typical model of an UAN. The term, "AUV" in the figure means Autonomous Underwater Vehicle. An AUV is basically a robot (unmanned underwater

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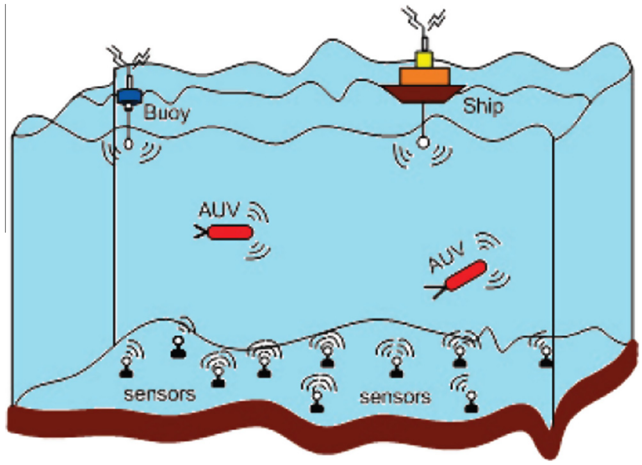

Fig. 1. A Typical Model of Underwater Acoustic Network.

vehicle) which travels underwater without requiring input from an operator. Such a scenario needs efficient way of operation at every stage including routing issues as multiple technologies get blended and should work together during its implementation.

To define formally, a routing metric is a value which is assigned to each route and used by a routing protocol to find a suitable route or a subset of routes from a set of discovered routes [3]. The objective of a routing algorithm is to utilize a routing metric to achieve one or more goals; for example, to maximize throughput, to minimize delay, to maximize end-to-end packet delivery, to minimize energy consumption, to distribute traffic load equally, and so on. Expected goal(s) may vary according to the network architecture and/or application. For instance, a wired network does not have any power supply constraint and it experiences noises in lower magnitude than terrestrial wireless networks. Consequently, most of the routing protocols engaged in wired networks utilize hop count as a suitable metric. However, in [4], it is demonstrated through experimental results that hop count metric is not a compatible metric for terrestrial networks. Active probing based routing metrics[1] are capable of attaining high throughput in such networks. Nevertheless, for exchanging probing packets among the neighbors, a considerable amount of energy is dissipated. Any network architecture, like a UAN, where nodes operate in battery power could not endure that energy waste. Therefore, a UAN's architecture prefers those routing metrics that require lower energy to deliver a packet since most of the nodes operate on battery power and thereby, topology-based routing metrics[2] are preferred over active probing based routing metrics. This is the core reason that we only consider topology-based routing metrics in this paper.

The rest of the paper is organized as follows. Existing routing metrics proposed for UANs and motivation of our work are discussed in Section 2. We describe our proposed metric in Subsection 3.1 and other metrics in Subsection 3.2 under Section 3. In Section 4, we present the underwater channel model considered in this work. Section 5 demonstrates the numerical results obtained employing the channel model discussed in Section 4. Simulation scenario and considered parameters are detailed in Section 6 along with the routing protocol where all the investigated routing metrics are embedded in. Simulation results and analyses are presented in Section 7. Our findings end with the concluding remarks in Section 8.

2. Related works and motivation

Among all the topology-based routing metrics, the minimum hop count is embedded in most of the routing protocols of any network architecture. Likewise, routing protocols proposed in [8–10] for UANs also utilize minimum hop count metric to select a suitable path. Generally, when a hop count is minimized, the distance between adjacent nodes is maximized, which is likely to maximize the loss ratio by minimizing the signal strength [4,11]. This phenomenon is prominent in UANs where a signal can travel several kilometers.[3] Moreover, because of the higher bit error rate of underwater channel, the probability of a packet loss is even higher [1,2]; which suggests an alternative routing metric.

A couple of routing metrics are proposed in various literatures for UANs. In [15], a topology-based routing metric, called low propagation delay is proposed. However, a path chosen using low propagation delay metric may not be able to attain

[1] A routing metric which does not exchange any probing packet to select a suitable path is known as topology-based routing metric, e.g., minimum hop count, minimum delay, average SNR, etc. [3].

[2] A routing metric which exchanges probing packets to select a suitable path is known as active probing based routing metrics, e.g., etx [4], rtt [5], ett [6], context-aware routing metric [7], etc.

[3] Currently, many modems are available that support transmissions over several kilometers of distance. For instance, the LinkQuest UWM2000 and UWM3000 modems support 1.5 km and 3 km, respectively [13], AquaComm supports ranges of 3 km [12], and the Evologics S2C R 48/78 modem supports 3.2 km [14].