Background and Problem

The need to underwater communication has increased rapidly as the role of autonomous robots grows. The vast majority of goods transported are shipped via ocean routes.

Most wireless communication above water uses electromagnetic. High frequency electromagnetic waves commonly used for communication (cellphones, WiFi, etc) dissipate extremely quickly underwater, rendering them impractical. Low frequency electromagnetic waves require large unwieldy antenna.

Acoustic communication underwater is possible, but there are some differences from electromagnetic waves. Since acoustic waves travel much slower and reflect more easily than electromagnetic waves (in normal use), the protocols used for electromagnetic waves cannot be efficiently be applied directly to acoustic communication. waves. The physical considerations of an underwater environment are primarily: attenuation, Doppler shifting, multipath interference, and noise [1].

Recently, there has been active interest in research about MAC protocols for underwater acoustic sensor networks (UAWSN). Research has focused on sensor networks over longer distances than we are concerned with. These networks often require data packets to hop through multiple intermediate channels before reaching their destination [2, 3].

Much of the current research into UAWSN, has prioritized the throughput as a function of offered load, with little consideration to the average propagation time of a signal. Some such protocols stop communication between a pair of nodes entirely, until other nodes have finished communication [2].

If the primary goal is communication between humans, or other devices requires timely and frequent communication, current MAC protocols for underwater environments are suboptimal.

In short range mobile networks, the average distance between nodes is much shorter than in a UAWSN typically considered in most research papers (often under 100m in comparison to 1-10km). The propagation delay of these systems is therefore at least one order of magnitude lower. However this delay is still much longer than the delays corresponding to EM communication over all common distances. Therefore there is a need for continued research into this middle ground. Investigating MAC protocol designed specifically for short range and low propagation delay will produce a significantly more efficient communication network for short range mobile networks.

Proposed Study and Approach

I propose an extension of Lin and Chen's MHM protocol to short range mobile networks, optimizing for lower, but variable, propagation delay. In particular, I hope to add metadata to the RTS packets in order to optimize the scheduling of data packet transmission.

In UAWSN, nodes are generally fixed. In an underwater mobile network, node clearly move, and often they move along non-deterministic paths. Any motion will induce a Doppler shift in the signal, something which must be accounted for. Since this is simply a scaling of the signal frequency, this can be accounted for by listening to a slightly enlarged frequency band.

A larger concern is that for any two nodes, the propagation delay of subsequent communications may not be known. The MHM protocol outlined by Lin and Chen relies on using the known propagation delay between two nodes to determine when future data packets should be sent. **In order to adapt this protocol to a mobile network, information about how propagation delays evolve over time must be considered.** My initial approach to this issue will be to explore the use of adding a small amount of metadata to the RTS (request to send) packets, in order to help predict how the propagation delay will change over time.

Designing such packets is of course the bulk of the work. RTS packets must remain small enough to avoid collisions with RTS packets from other nodes. At the same time, they must contain enough information for a node to determine the scheduling for outgoing CTS (clear to send) and incoming data packets. In order to determine how to minimize the data contained in the RTS packets, it is essential to know the motion of the nodes. This is not an easy problem. Without a positioning system such as GPS, absolute positions can not be known. If the receiving node does not know the orientation or orientation of the other node, then even knowing the direction of motion may not be sufficient. My initial work will then be to understand the type of positioning information available, and how it can be effectively transmitted.

Resources Needed

While the strict requirement for this project is only the computation platform needed to run simulations, I hope to be able to collaborate directly with researches at Chinese institutions such as Minjiang University, where communication protocols for underwater acoustic networks are an active research topic. As I discussed in my personal statement, it is important to me that I begin collaboration with international research communities early on in my professional development. I have already started to reach out to potential collaborators.

[1] M. Stojanovic, “Underwater acoustic communication,” *Wiley Encyclopedia of Electrical and Electronics Engineering*, 1999; revised and updated 2015.

[2] B. Peleato and M. Stojanovic, “Distance aware collision avoidance protocol for ad-hoc underwater acoustic sensor networks,” *IEEE Communications Letters*, vol. 11, 2007.

[3] W. Lin and K. Chen, “MHM: A multiple handshaking mac protocol for underwater acoustic sensor networks,” *International Journal of Distributed Sensor Networks*, vol. 2016, 2016.