Networking Across Boundaries: Enabling Wireless Communication through the Water-Air Interface

Wireless communications across different mediums is challenging, because of the different ways the communication channels behave and propagate information. Translational Acoustic-RF communication (TARF) tackles the communication barrier between water and air mediums. At the basic level, TARF uses acoustic underwater transmitters that displace the surface of the water. On the receiver side in the air, TARF uses a FMCW radar which measures the physical displacement of the water and decodes that information.

The TARF design addresses several of the significant challenges associated with communicating across mediums. However, TARF can only perform one-way communication, as the airborne radar is unable to send feedback to the underwater sensor. TARF can use a pressure sensor to estimate the depth of the sender, which allows it to do bitrate adaptation. Because of the use of a FMCW radar and filtering techniques, TARF can mitigate the impact of interference and noise.

The motivation for TARF is largely focused on deep sea applications. In particular, the authors mention the security risks associated with a submarine needing to surface to communicate with an airborne drone (and thereby revealing its location). They also mention the difficulties associated with networks that rely on autonomous underwater vehicles (AUVs) to dive down into deep sea and collect information from sensors. In our discussions, we believe that TARF is more a proof-of-concept, and its current design does not fully address the scenarios in the motivation.

The TARF design is dependent on the vertical alignment of the underwater sensors and the airborne radars. As the misalignment grows to over 20cm, there is a significant performance degradation. This alignment requirement could reveal the location of underwater sensors to an adversary, which does not alleviate the security risks of current networks.

Additionally, the TARF design and evaluations were not targeted towards deep sea applications. The authors admit that a limitation of TARF is its inability to perform in inclement weather (e.g., wind waves, rain). We believe that salt spray could significantly impact the performance of TARF, along with the weather conditions mentioned by the authors.

The authors evaluate TARF in two scenarios: in a water tank with manually generated waves, and in a swimming pool during normal activity. Their evaluations measured how well TARF performed for a selection of sensor depths and alignments, along with its robustness to waves. TARF's throughput drops to zero for waves larger than 22cm, but we believe that there could be optimizations that allow it to handle this scenario, and this should be considered for future work.

We believe there are many opportunities for a more extensive evaluation. Specifically, an investigation of the SNR vs the receiver height would give more insight into the type of applications that are feasible with TARF. If the radars were placed higher, might this result in more forgiveness for misalignment? Additionally, the evaluations on radar height and sensor depth were somewhat limited. TARF should be evaluated at depths that more closely match deep sea applications to provide a better understanding of its feasibility.

Overall, TARF is a promising first step to better addressing the problem of multi-medium wireless communication. Despite having limitations, TARF cleverly uses physics to successfully send information from underwater sensors to above-ground radars, in the presence of wave interference. The authors also describe several opportunities for future research, including adapting TARF for bi-directional communication, inclement weather, and more forgiving alignment.