Underwater Networking Research at USC/ISI

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Sensor networks have seen a new focus of development by DARPA, NSF, academia and industry since 1999. The key benefits of terrestrial sensor networks stem from inexpensive nodes, placed near what is being sensed, sharing a short-range wireless network. By comparison, underwater sensing today is often expensive, sparsely deployed, and wired, or with very limited, point-to-point acoustic communication.

The goal of the SNUSE project [1] bring the benefits of terrestrial sensor networks underwater. To this end we are developing new approaches for *hardware*, with a new inexpensive, short-range acoustic modem [5], and *network protocols* tuned for high-latency, low-bandwidth operation, including new time synchronization [3] and underwater media-access protocols (MAC) [4].

Our goal is to allow deployment of networks of hundreds of inexpensive (less than US$1000) underwater sensors in relatively dense configurations (perhaps a 1–20km^2 area). Each sensor will detect and process data locally, communicating results over a multi-hop acoustic network. One or more nodes may have external network connections. Operating on battery power, sensor nodes must carefully monitor their energy consumption, and all components of the system are designed for low duty-cycle operation. We are currently exploring applications for industrial and scientific monitoring [2]; military surveillance is also possible.

Hardware design: Our acoustic modem design [5] targets short-range operation (50–500m) to reduce the underwater communications challenges that grow with distance, such as multipath reflections, temperature variation, and surface scattering. We use simple FSK signaling and expect about 1kb/s bitrates with our current design.

One innovative aspect of our hardware is support for a very low power *wakeup receiver*. This receiver is not intended for data exchange, but to allow neighboring nodes to indicate interest in sending traffic. With only 500μW power draw, it can remain vigilant frequently to allow rapid activation of the network when an event occurs.

Time synchronization: While there are many time synchronization protocols for terrestrial wireless networks, none consider operation in high-latency acoustic networks. We have shown that latency must be considered for acoustic networks at distances greater than 100m, and defined a new protocol, TSHL [3] to do so. TSHL splits time synchronization into two phases: In the first phase, nodes estimate clock skew relative to a centralized timebase. In the second phase they swap skew-compensated synchronization messages to determine their clock offset.

Media-access protocol design: The key challenge for MAC protocol design is managing the large latencies that occur over even short distances in an acoustic network (more than 300ms at 500m). Our current design, ST-Lohi [4], exploits the wakeup receiver described above to reserve the channel, and it uses a novel approach to count the number of contending nodes. We show that it is both stable over a wide range of offered loads, and also that this ability to count contenders improves fairness when the network is busy.

Ongoing work: Our work in these areas is ongoing. Our current focuses are completing hardware/software interfaces for our acoustic modems, more fully evaluating our MAC protocol design, and evaluating our work through both in-the-air and planned underwater acoustic experiments.

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Jack Wills is a computer scientist at USC/ISI in the advanced systems division. He has a PhD in Electrical Engineering. His research interests are analog circuit and RF design, and he leads the hardware design of the SNUSE analog modem.

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