Demo Abstract: A Sensornet-inspired Underwater Acoustic Modem for Wake-up and Data *

Affan A. Syed, Muhammad Omar Khan, John Heidemann, Jack Wills, Wei Ye
USC/Information Sciences Institute, {asyed,omarkhan,johnh,jackw,weiye,}@isi.edu

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Wireless communication; Distributed networks

1. INTRODUCTION

Sensor networks are changing how data is collected in many applications on earth today. However, today's sensornets do not address the 71% of the earth's surface that is covered by water. Just as sensornets benefit environmental monitoring and industrial control on land, environmental monitoring in oceans and lakes, and control of underwater industrial processes can benefit from sensor networks [4, 2].

While underwater sensornets can exploit the same computation and storage approaches of terrestrial sensornets, radio networks are simply not viable underwater because water absorbs most radio frequencies. Acoustic modems are a viable alternative, but most commercial acoustic modems today target long-distance, point-to-point communication with high-power consumption and high costs. While matched for some vertical applications that are fielded today, these modems are the antithesis of a sensornet, which calls for short-range, low-power, many-to-many communications, and small, inexpensive platforms.

We are developing a new underwater acoustic modem targeted at the needs of sensor networks [8]. Our design targets low cost (∼$100, plus hydrophones), short range (less than 500m), and relatively low bit rates (1kbaud). As with sensornet radios, we support transmit power control and exploit CPU capabilities to get the flexibility of software-level bit decoding. A unique feature of our modem is an ultra-low-power wake-up circuit (100μA at 5V), which can be activated by a short wake-up tone. We exploit wake-up tones by developing T-Lohi, an underwater media access protocol that is efficient in both energy and throughput [7].

This demonstration will show both data transfer and wake-up tone activation. We will show end-to-end data transmission (PC-to-PC, through motes operating as NICs, modems, and hydrophones in water). This demonstration is an extension of a demonstration that will be shown at Sensys 2008 [6][1]. We will show tone-triggered modem wakeup, highlighting low energy consumption accomplished by disabling data receive and employing only an energy-optimized wake-up tone receiver. Beyond the Sensys demo, we will show tone-triggered activation of data reception.

2. MODEM OVERVIEW

2.1 SNUSE Acoustic Modem

Our SNUSE modem is designed to capture the key aspects of RF-based sensornet platforms (such as Mica-2 and MicaZ motes with Chipcon CC1000 and 802.15.4 radios) in an underwater, acoustic environment, first described in WUWnet [8]. We lay out our design goals above, focusing on low power and cost. In addition, it includes support to ease testing and development, such as optionally independent transducers for transmission and reception, and support for both in-air and underwater acoustic operation. Other acoustic modems currently exist, however these modems do not share the same goals of our low-power, low-cost, and short range communication [9, 1].

The basic modem design operates with FSK modulation over the 17–19kHz range. It is designed to operate at 1 kbaud, although we currently underclock it at 512 baud. We expect to operate at full speed in our next hardware revision, version 3 planned in late 2008.

The modem incorporates a custom wake up receiver, listening for wake-up tones at 18kHz. This wakeup receiver can trigger modem operation even when all other components are powered down; in this modem it draws only about 100μA at 5V. Our T-Lohi MAC protocol (described in Section 2.3) uses tones to provide energy-conserving signalling.

2.2 Physical-Layer Software Implementation

The hardware described above provides basic functions of transmitting and receiving raw bits and wakeup tones. To support packet-level communication, we implement other physical layer components in software on a Mica-2 mote that runs TinyOS [5, 3].

We divide the physical layer into two components. The lower level one controls the modem states, and performs start symbol detection, bit-level transmission and reception, transmit power control, and RSSI measurement. The higher level component provides a packet-level interface to MAC and other applications. It performs channel coding, CRC checking, and time stamping on each each packet.

We use a software-level synchronization algorithm to cope with modem clock variance and Doppler shift in moving nodes. For each incoming symbol, we take three samples and vote to determine a value. If the first or last sample is consistently out-voted, we resynchronize timing of symbol alignment. Our experiments show that the bit re-sync

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[1]Portions of this abstract are common with the Sensys demonstration abstract, with permission of both organization's demonstration chairs.

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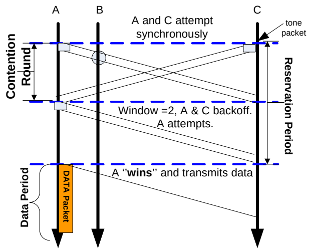

Figure 1: The Tone-Lohi protocol frame

algorithm can improve our packet reception rate from 40% to 100%.

2.3 Planned Media-Access Layer

The primary objective of our underwater MAC protocol, T-Lohi [7], is to provide efficient channel utilization, stable throughput, and low energy consumption. T-Lohi makes data packet collisions unlikely by use of contention to reserve medium, thus avoiding loss of throughput and energy waste. T-Lohi also exploits our modem's low-power wake-up receiver by using wake-up tones to indicate contention, further reducing energy waste [8].

In T-Lohi MAC, nodes contend to reserve the channel to send data. Figure 1 shows an example of this process: nodes A and C have data to transmit but first send tones indicating contention in fixed length rounds. Detecting other tones provides a count of current contenders: A and C have a count of two and back-off to attempt uniformly in one of the next *two* rounds. If no other tone is detected in a given round (as A does in round two), collision free data transmission occurs in the subsequent round.

We are in the process of implementing T-Lohi on our hardware. In this demo we demonstrate low-power wake-up circuit at the core of T-Lohi.

3. DEMONSTRATION

We have operated our modem in several environments, including in-air testing with tweeters as actuators, water tests in the laboratory, and water tests in the Marina Del Rey harbor. For WUWNet we will show our demonstration in a tub for ease of deployment. Our experimental setup can be seen in Figure 2. Our demonstration will have several components: data transmission, PHY demonstration, and wakeup demonstration.

For *data transmission*, users will type in a message on the sender PC. The PC will pass the user data to the Mica-2 mote via a serial cable. The software on the mote arranges the text in to an appropriate packet format, and performs channel coding and CRC calculation. The mote the derives the modem transmitter to send each bit out to the attached hydrophone. On the receiver side, the packet gets picked up by the receiving hydrophone. The receiver-side modem does hardware detection and provides an analog bit pattern. The receiver's Mica-2 mote performs bit detection and synchronization as well as packet framing and decoding. After checking the CRC, it passes the packet to the PC to display the packet content.

To demonstrate our *low-power wake-up circuit* we use a modem board with wake-up capabilities. Currently our modem is in integration phase with separate boards for data and wake-up. We are working on the possibility of integrating the two boards for a unified final demo. Modem's power consumption and state changes will be visible on an oscilloscope. For our demo, we initialize the modem into *vigilant sleep* (only wake-up receiver on). A user will then generate an 18kHz tone on a PC connected to an underwater transducer. This will cause our modem to wake-up and transition to an active state; with a visible increase in power drawn. The oscilloscope will also show a modem generated interrupt that is to be used for waking up processors in deep-sleep.

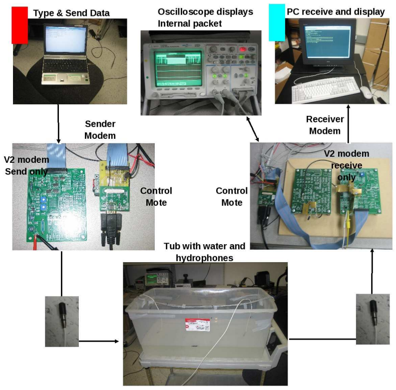

Figure 2: Hardware setup for demonstration of through-water data transmission.

To demonstrate integrated tone-data operation, we will operate the modem in *vigilant sleep* mode, where only the wake-up receiver is powered on. We will show how the wake-up tone can activate the full data receive hardware. Our full modem design will integrate wake-up and data transmission and reception on one board, but for ease of development, our current implementation will use two half-populated boards tied together.

4. REFERENCES

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