

INTERNET OF THINGS OF THE SEA

Project Overview

- Researchers at Pacific Northwest National Laboratory (PNNL) and other marine scientists deploy many underwater sensors to collect real-time marine data.
- Data retrieval currently involves recovering the devices to retrieve the data, which is costly in time and money.
- The objective is to design and implement a wireless underwater communication system to eliminate the need for frequent retrieval of the sensors.
- We developed an open-source, low-power communication system that can be integrated with an ROV (Remotely Operated Vehicle) and the sensor network.

Key System Requirements

- Our system must transfer 1MB file/hour with 1 meter difference in nodes.
- Must have two nodes that communicate with each other bi-directionally, in a half-duplex manner.
- Able to transmit data in a 30 m underwater environment under pressure.
- All hardware must fit into an enclosure the shape of a 1 L bottle.
- Must be driven by one 12V power supply.
- Our system must be low power, drawing around 5W.

Communication Medium: Acoustic Hydrophones

- Acoustic hydrophones are omnidirectional, which is optimal for unpredictable marine conditions.
- Hydrophones are capable of both transmitting and receiving.
- Factors such as power consumption, novelty, or signal attenuation favored acoustic over other mediums.



AS-1 Hydrophone



Underwater Hydrophone Testing Setup



ELECTRICAL & COMPUTER ENGINEERING UNIVERSITY of WASHINGTON

STUDENTS: BINGAN CHEN, LIZ HUANG, SARA KUMAR, ANTHONY MCKEIRNAN, TIMOFEY POPOV, MICHAEL TSIEN, XUKANG WANG

- Hardware
- Raspberry Pi 5s handle data processing, protocol logic, and TX/RX switch control.
- A custom preamplifier boosts the received signal.
- TX/RX Switch is used to select the receive or transmit signal path to mitigate collision.



Communication

- Utilizes 63/67 kHz binary frequency-shift keying (BFSK) with Goertzel-based demodulation for noise-resistant, low-power underwater data transfer. FFT-accelerated cross-correlation enables real-time preamble detection and precise
- symbol alignment.
- Implements CRC-8 to detect transmission errors and ensure data integrity in every frame.
- Communication is facilitated through a state-based protocol which requires handshaking and response signals to improve reliability.



ADVISERS: EMMA GEON, ALEX TURPIN, AKSHAY GADRE SPONSOR: PNNL – Pacific Northwest National Laboratory

- Achieved reliable bidirectional data transmission using hydrophones in **1-meter-deep underwater environment.** Designed and implemented a robust protocol featuring handshake,
- authentication, error checking, and retransmission.
- Reached 1 kbps data rate with bit error rate <10% and packet loss <15% under real water conditions. Kept system power efficient when provided 12V we pull a total of:
- 0.24W when OFF
- 3.24W when ON (idle)
- 4.80W when ON (transmit)
- 5.64W when ON (receive)
- Implemented wake-up hardware that wakes up system when ROV node is near to save power when not actively transmitting.
- Implemented battery-monitoring circuitry to shut-off system and let battery regenerate to healthy voltage.



Top Left: Housing Mechanical Design

Top Right: Hardware System

Bottom: Housing Interna and External Views

like an ESP32 or STM32 microcontroller.

- Improve data rate by utilizing a more bandwidth-efficient protocol like orthogonal frequency-division multiplexing (OFDM) or decreasing symbol time.
- Implement encryption for secure data transfer. Design and manufacture custom PCBs to hold the hardware circuitry.



Results

- Target system cost: \$2,500
- Actual system cost: \$1,007.21



Future Work

Decrease power consumption and cost by moving to a smaller processor