Cognitive Acoustic: Making Underwater Communications Environment-friendly

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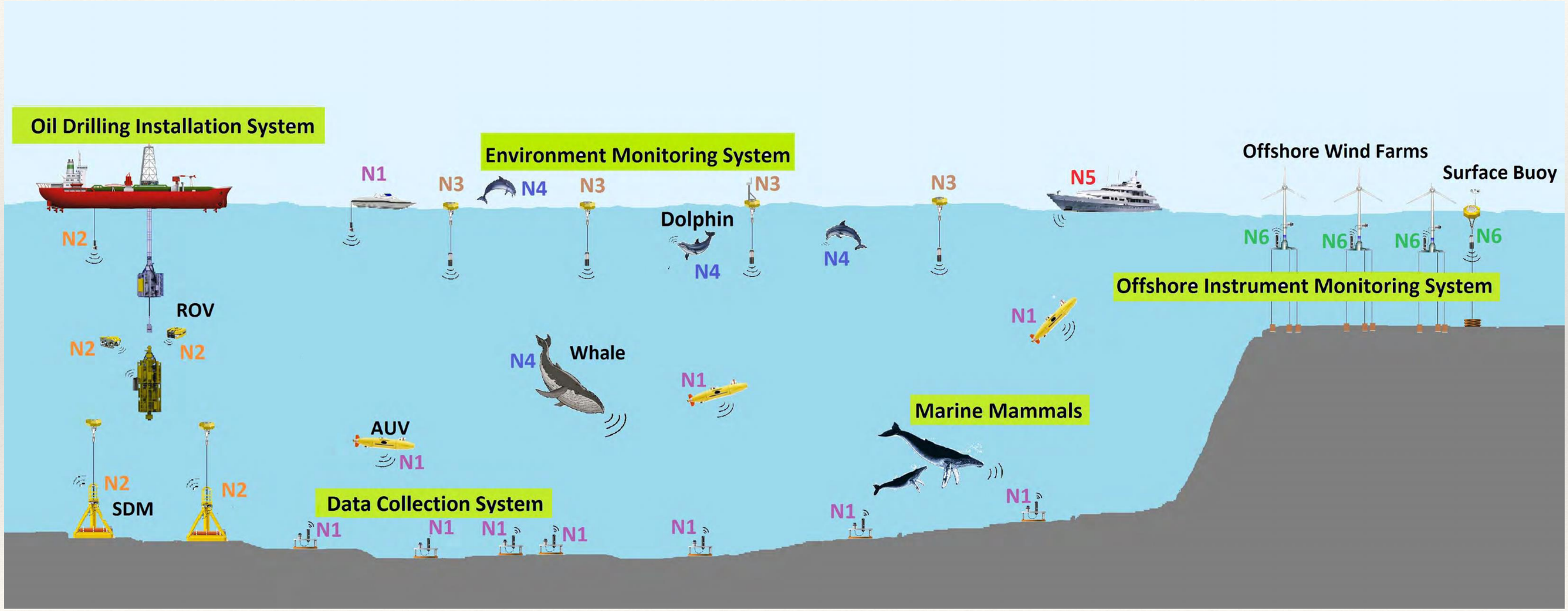
Presented by **Zheng Peng**

Underwater World with Multiple Acoustic Systems



Underwater wireless networks share channel resources with multiple acoustic systems in the ocean

Current Underwater Communication Technology

- Currently, we use the acoustic channel aggressively
  - We do not consider the existence of other acoustic user

    —> **poor scalability**
  - We also ignore the activity of marine animals

    —> **poor sustainability**

- Develop an intelligent underwater acoustic networks for **green**, **reliable** and **efficient** communications

Collaborative Research

- NSF Award 1331851, 1441253 and 1331873:
  - "A Pilot Study on Cognitive Acoustic Underwater Networks for Sustainable Ocean Monitoring and Exploration."

- Three U.S. institutions:
  - University of Connecticut, PI: Zheng Peng
    - Networking
    - System/Testbed
  - Virginia Commonwealth University, PI: Wei Cheng
    - Modeling
    - Optimization
  - Georgia Institute of Technology, PI: Mardi Hastings
    - Marine bioacoustics

The Solution

- **The Underwater Cognitive Acoustic Network (UCAN) :**

  - **Environment-friendly transmissions:** Users in UCANs suspend transmitting or switch to other vacant frequencies when the presence of primary users (PU) is sensed.

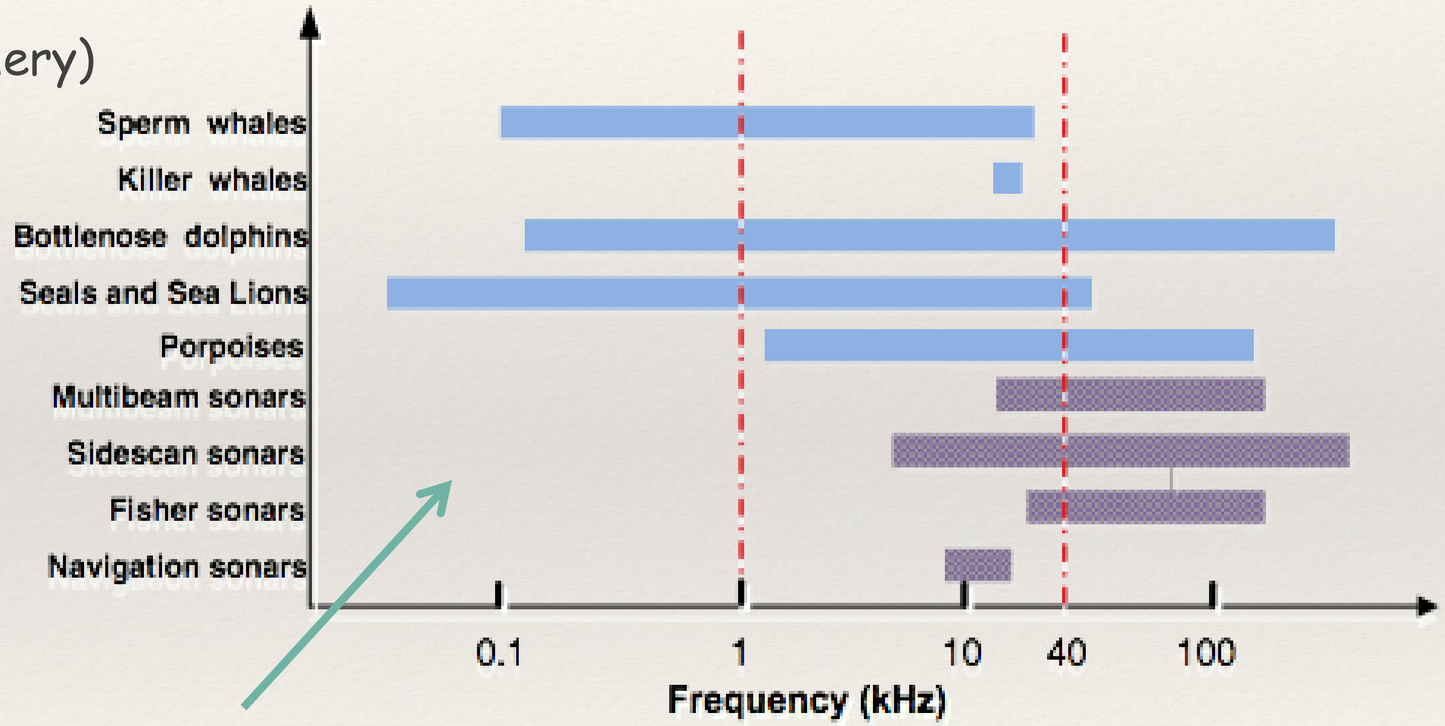
  - **Channel-efficient communications:** high throughput, efficient channel utilization and short end-to-end delay

Challenges in UCANs

- **Limited bandwidth**
- **Challenging primary users**
  - Vulnerable
  - "Unreasonable"/Incooperative
- **Limited understandings on signal/user pattern**
  - How to detect the marine animal?
  - Need better understanding of animal behaviour
- **Large propagation delays**
  - Outdated sensing results can mislead the UCANs on making spectrum decision

Spectrum Usage

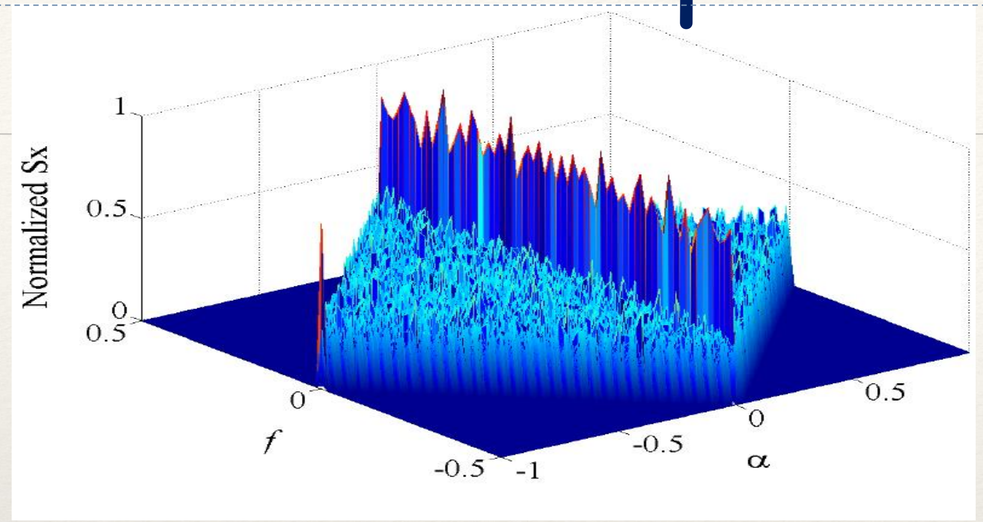
- **Acoustic channel is a precious resource**
  - **Human activities:**
    - Sonar (navigation/detection/fishery)
    - Underwater acoustic networks
  - **Marine mammal activities:**
    - Orientation/Echolocating
    - Tracking/Foraging
    - Communication



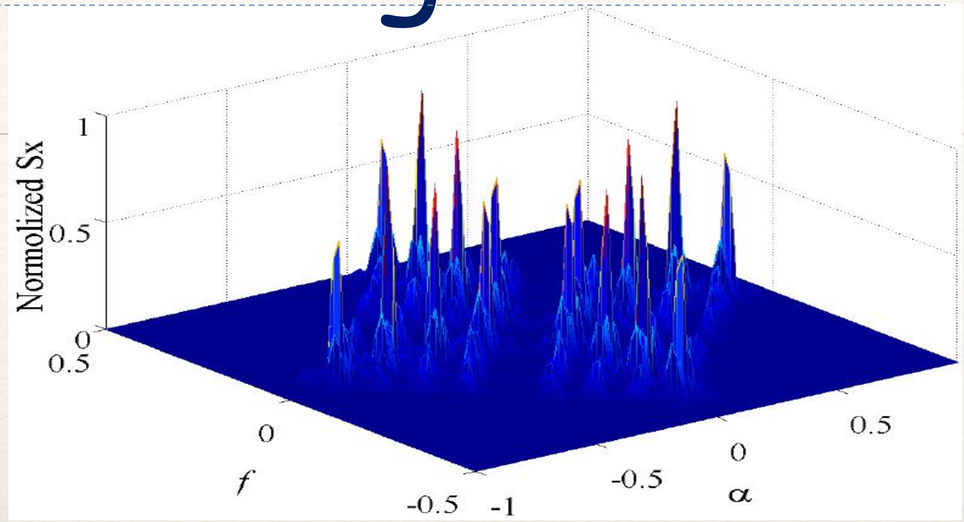
How to detect/differentiate them?

The spectrum usage of underwater users

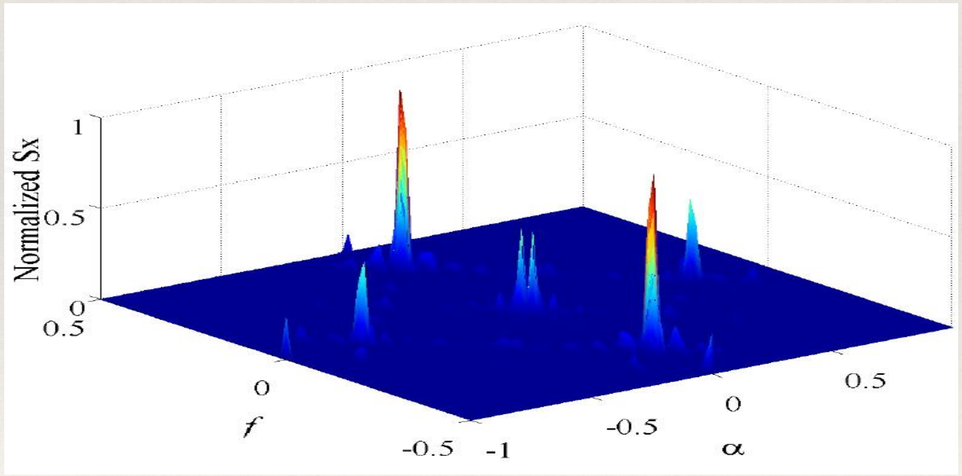
Spectrum Sensing



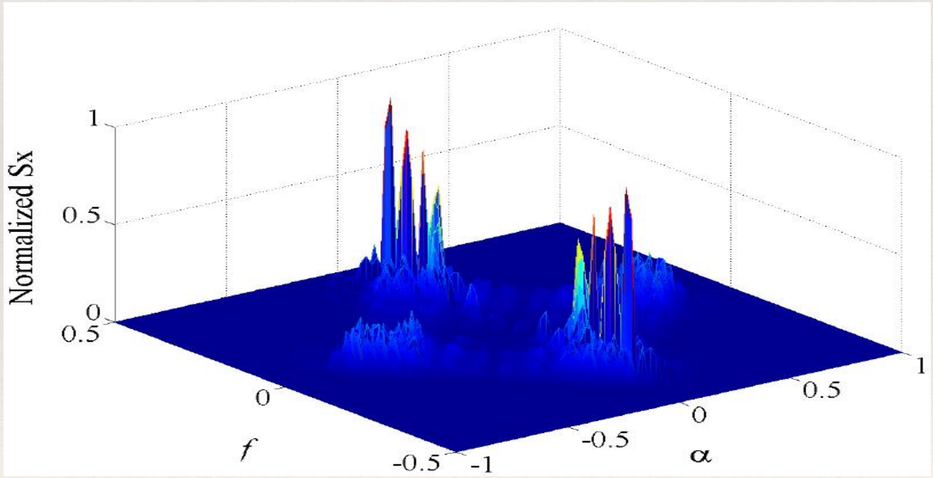
Ambient noise



4FSK



Dolphin



Minke

S_x: *cyclic cross periodogram* α: *nomolized cyclic frequence* f: *nomolized frequency*

Spectrum Management

- **Objective:**
  - Making decisions on channel access in terms of
    - Time
    - Frequency
    - Modulation
  - Allocating resources for users to
    - Avoid collisions and disruptions to primary users
    - Optimize the network performance in terms of throughput, energy, etc.

Summary

- Introduced the concepts of Underwater Cognitive Acoustic Networks (UCANs)
- Studied the challenges in UCANs

- Can we make the underwater communications more environment-friendly?

  Hopefully, Yes, UCAN!

Thanks and Questions

- Yu Luo, Lina Pu, Zheng Peng, Yibo Zhu and Jun-Hong Cui, RISM: An Efficient Spectrum Management System for Underwater Cognitive Acoustic Networks, in Proceedings of IEEE International Conference on Sensing, Communication, and Networking (SECON), Singapore, 2014.

- Yu Luo, Lina Pu, Michael Zuba, Zheng Peng and Jun-Hong Cui, Challenges and Opportunities of Underwater Cognitive Acoustic Networks, IEEE Transactions on Emerging Topics in Computing, vol. 2, no. 2, pp. 198 - 211, 2014.