Use cases for Underwater networking

Environment monitoring
- Review how human activities affect the marine echosystem

Undersea explorations
- Detect underwater oilfields

Disaster prevention
- Monitoring ocean currents and winds (Tsunamis)

Assisted navigation
- Locate dangerous risks in shallow waters

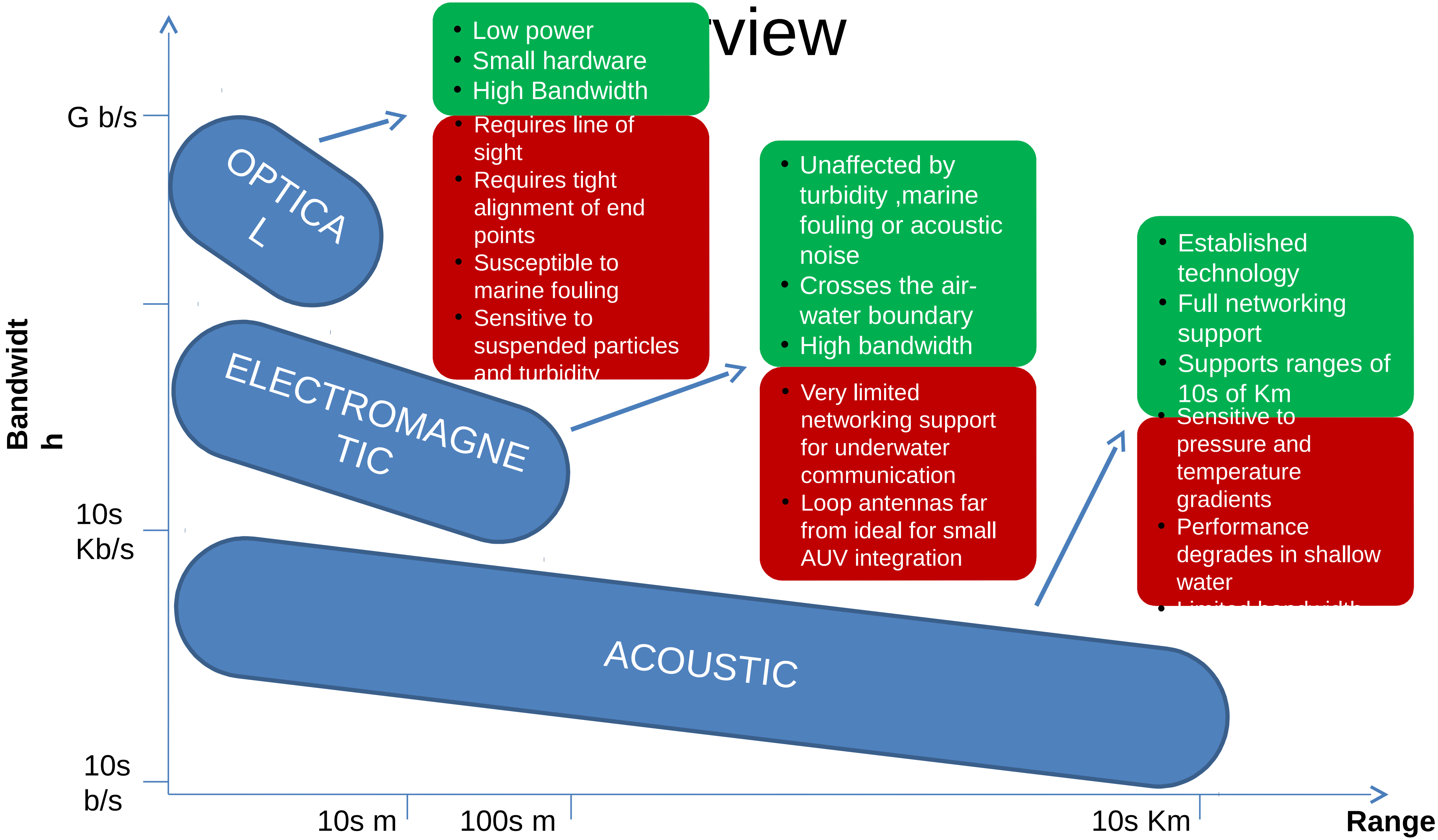
Distributed tactical surveillance
- Intrusion detection (Navy), harbour protection

…...

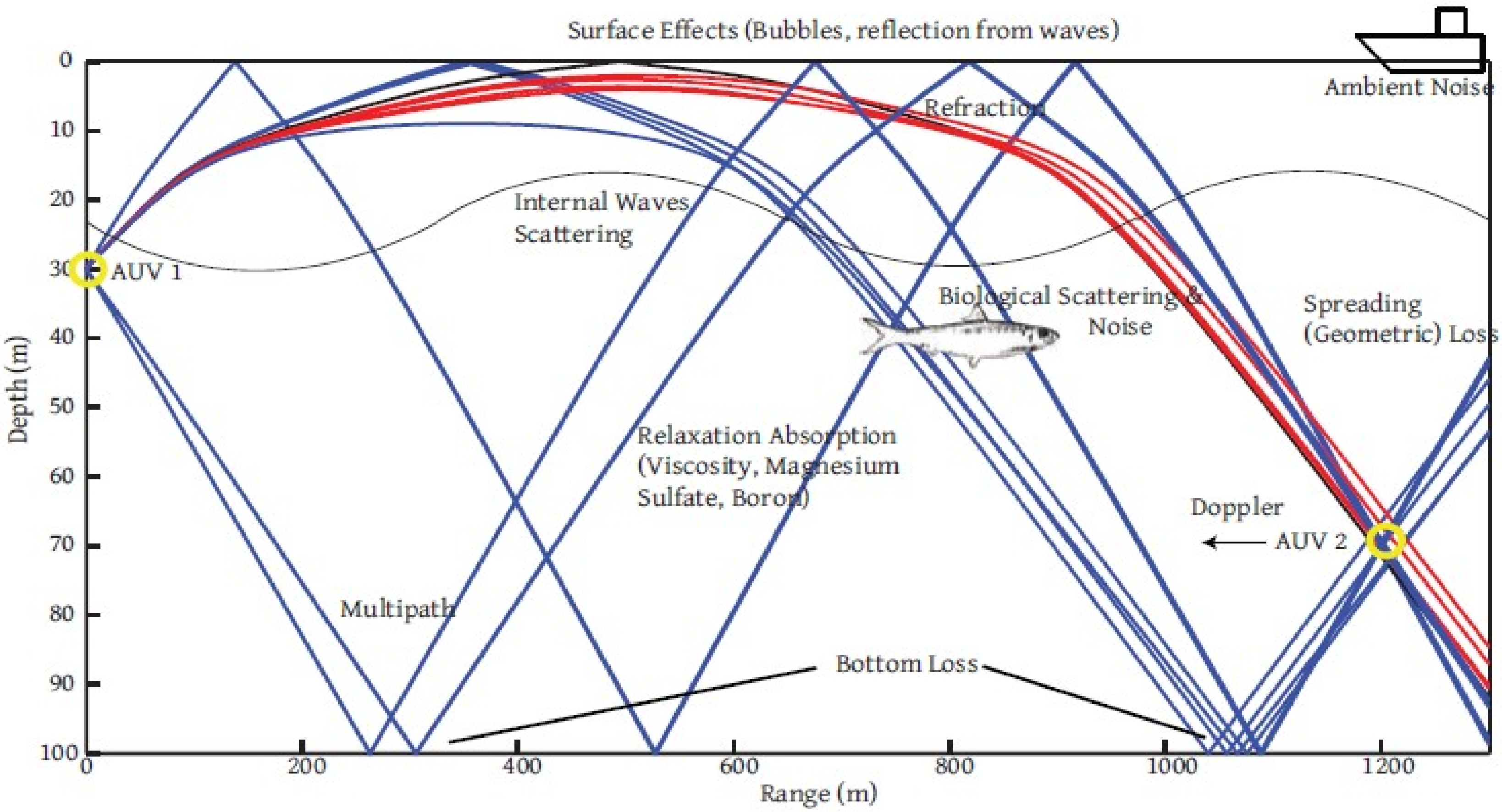
The Requirement for Underwater Communications

- We don't like our autonomous vehicles to be too autonomous
- Safety of operations
- Real-time data is usually a requirement
- Cooperation, in general, requires some kind of explicit information exchange
- Increased number of assets being deployed (currently from few up to 15 underwater and surface nodes)

UW Communications Channels: **Qualitative** view



Acoustic communications: The Channel



"Advances in Integrating Autonomy with Acoustic Communications for Intelligent Networks of Marine Robots", Toby Schneider, PhD thesis, 2013

Acoustic communications: The Channel

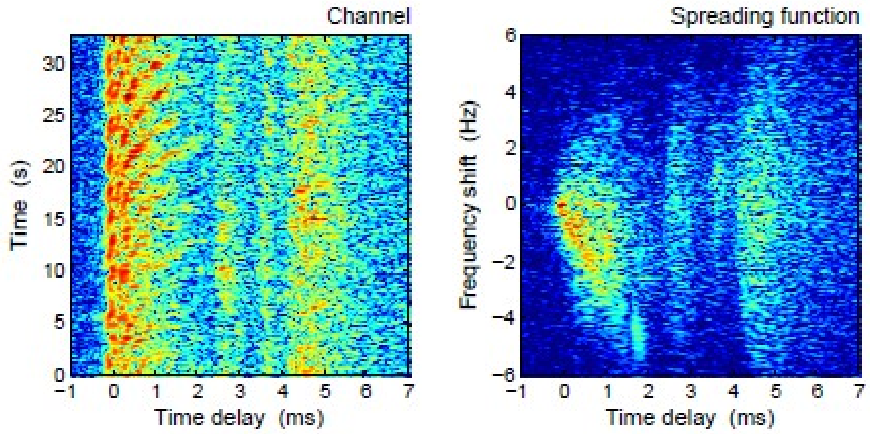
- Slow speed of propagation: five orders of magnitude lower than in Radio Frequency)
  - High Doppler shifts (example: v=2m/s, f=25 kHz, shift = 33 Hz)
- Spreading Loss
  - Energy covering a big volume
- Absorption Loss (Frequency Dependent)
  - Losses from energy propagation/ transfer
- Scattering Loss
  - Surface scattering – rough sea surface introduces rapidly fluctuating arrivals
  - Bubble layer scattering

Acoustic communications: The Channel

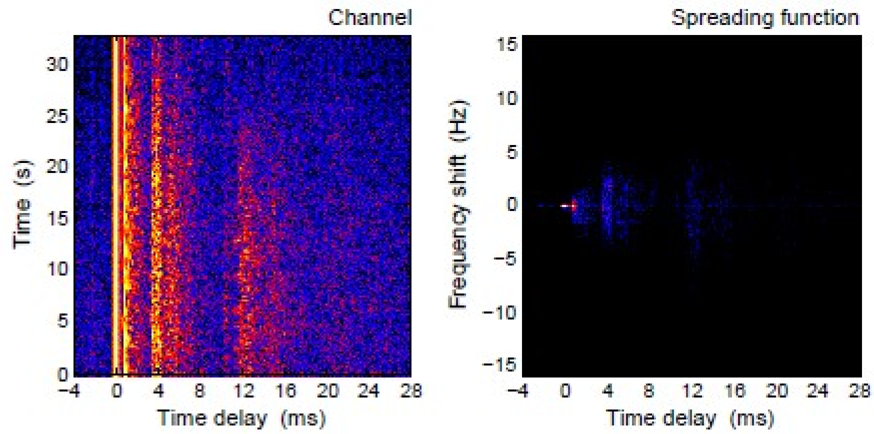
- Low Bandwidth
- Ambient noise and high interference level
- High bit errors and temporary loss of connectivity with possible asymmetric links
- Waveguide, multipath, shadow zones
  - Reflections from bottom and surface
  - Refraction form spatially varying sound speed
  - Masses of water with different characteristics
  - Imposes multipath and time spread –ISI

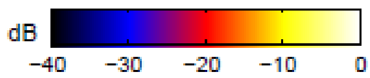
Channel Impulse Responses : Examples

Cyclic arrival agreeing with the period of the dominant waves



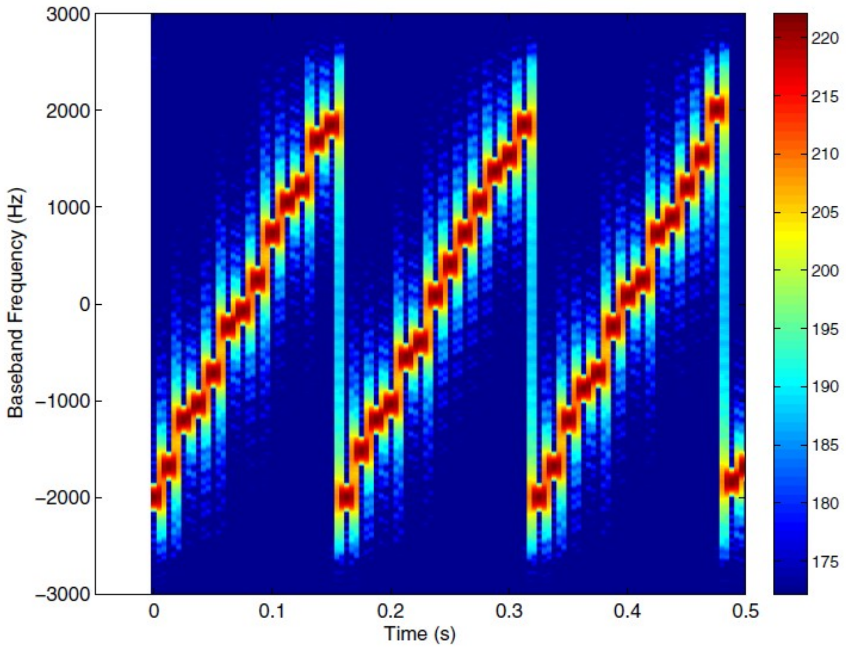
Wind burst at around t=25 seconds

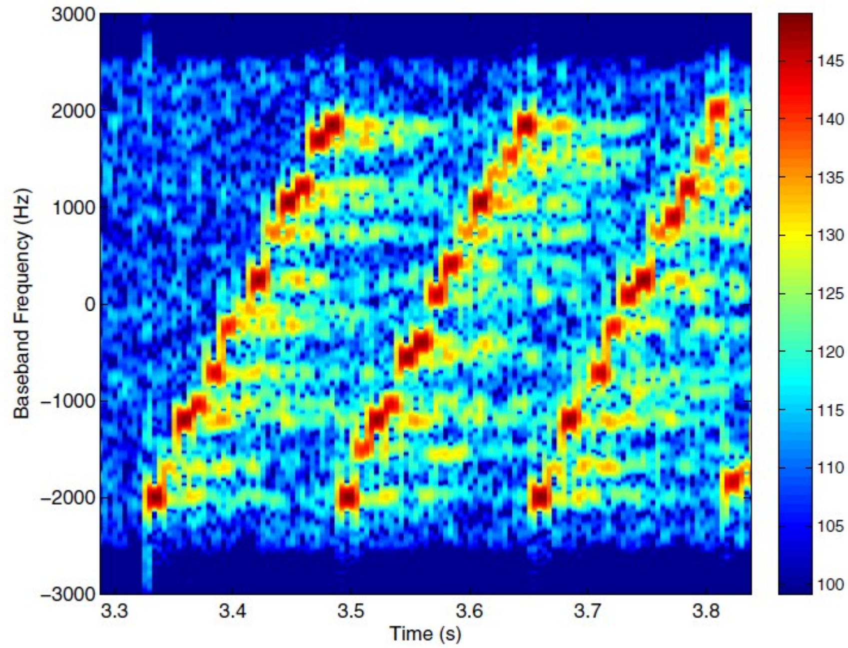




"Channel Sounding For Acoustic Communications: Techniques and Shallow Water Examples", Paul Van Walree, Technical Report 2011

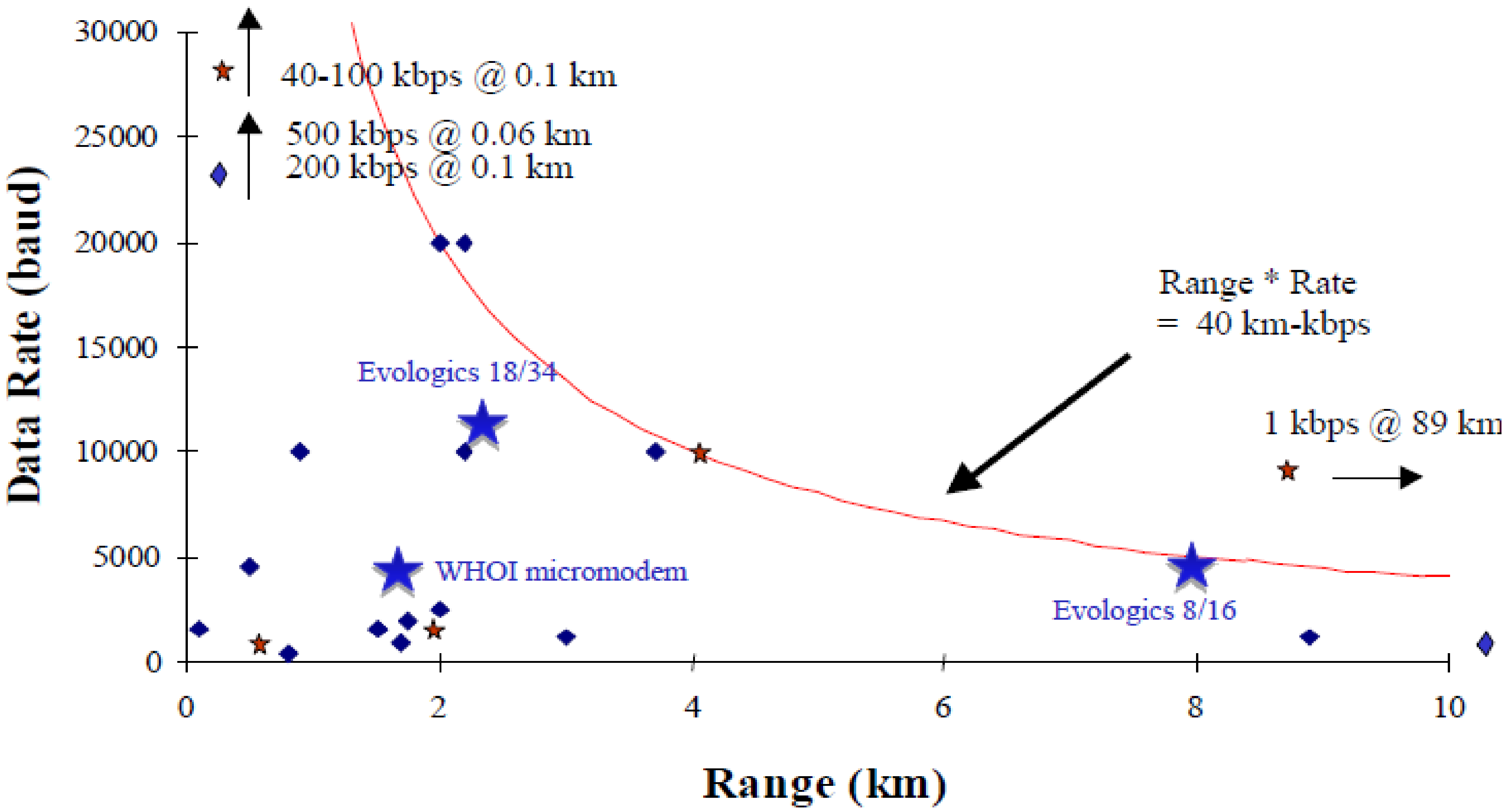
What a **very benign** acoustic channel will do to your signals





"Underwater Acoustic Communications Performance Modeling in Support of Ad Hoc Network Design", Fox, W. L J; Arabshahi, P.; Roy, S.; Parrish, N., OCEANS 2007 , vol., no., pp.1,5, Sept. 29 2007-Oct. 4 2007

UW Acoustics Physical Layer Performance



"The state of the art in underwater acoustic telemetry" Kilfoyle, D.B.; Baggeroer, A.B.; MIT & Woods Hole Oceanogr. Instn. Joint Program in Oceanogr. Eng., Woods Hole Oceanogr. Instn., MA IEEE Journal of Oceanic Engineering, Jan 2000

Challenges

- Interoperability is nonexistent !
- Software architectures based on the OSI stack fall short of providing cross-layer information essential for achieving optimized solutions
- There is no single adopted way to simulate the acoustic channel
- Usually simulations fail to fully capture underwater channel dynamics resulting in oversimplified scenarios
- Going at sea is expensive. Doing it in a controlled way even more so.
- Reliable and robust multi-hop communication coping with channel dynamics

Trends

- Interoperability will hopefully come ! JANUS is here, hopefully promulgated as a standard soon.
- Improved data throughput to be pursued by:
  - More sophisticated modulation and coding schemes, signal processing techniques.
  - Multi-carrier systems,
  - Multi-modality, hybrid systems
- Software-defined architectures will improve sharing of solutions and promote a true “survival of the fittest” in terms of protocol solutions
- Network security for underwater communications
- Combination of sensing, networking, communication and navigation capabilities to improve underwater node operations
- Network coding, data compression and DTN solutions