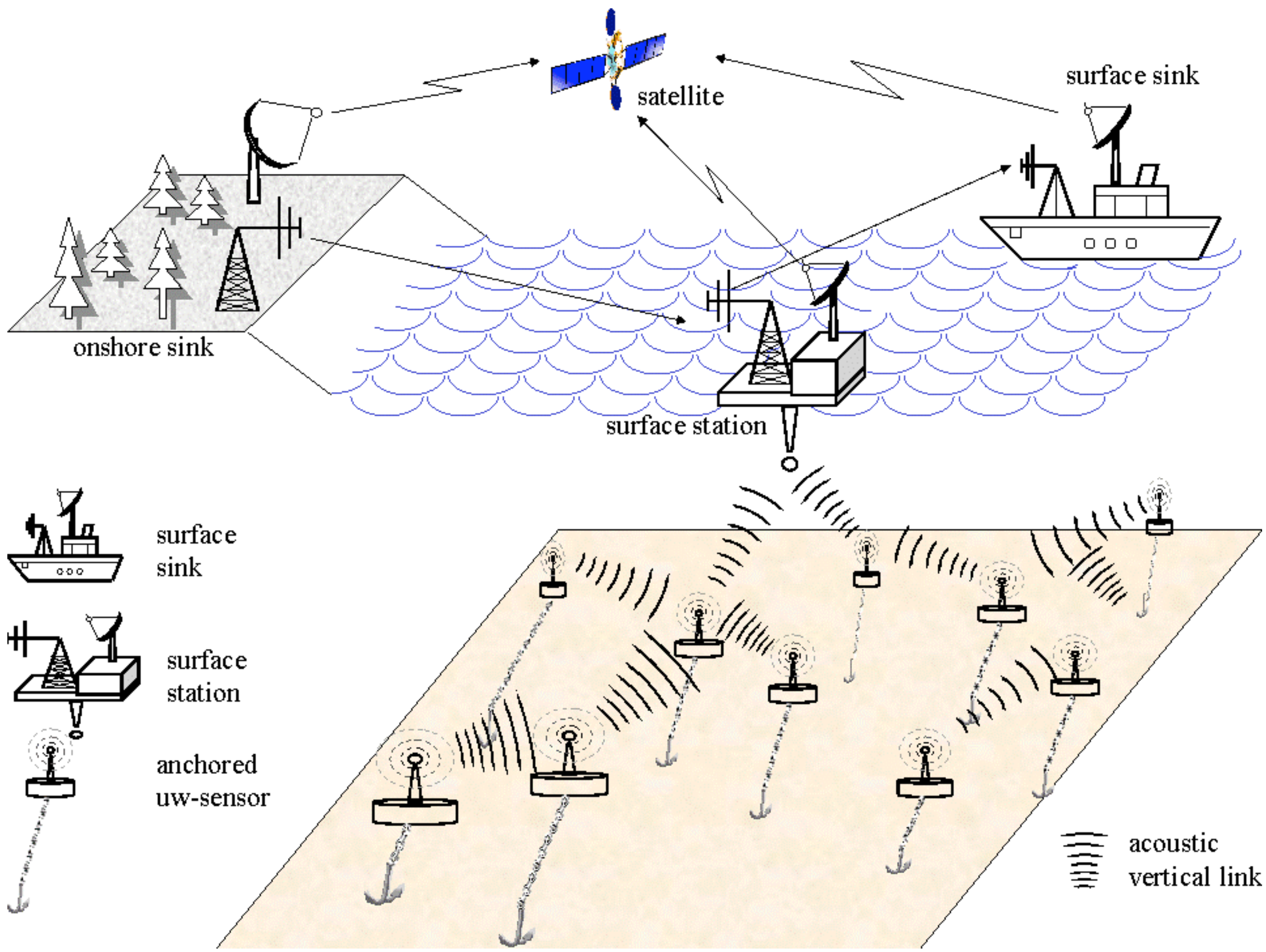
Overview: Underwater sensing

- Pompili, D., Melodia, T., and Akyildiz, I. F. **Routing algorithms for delay-insensitive and delay-sensitive applications in underwater sensor networks**. In Proceedings of the 12th Annual international Conference on Mobile Computing and Networking (Los Angeles, CA, USA, September 23 - 29, 2006). MobiCom '06

Underwater sensing

- Tethered: ocean floor/buoy, free floating, UUV/AUV



Newer challenges

- 3D sensing over a vast volume
  - Sensing seabed for underwater mineral deposits, submarine cables etc.
  - Monitor oceans for health/pollution
  - Surveillance/mine reconnaissance
- Unlike in terrastrial links, relatively simple to operate underwater vehicles

Differences with Terrestrial Networks

- **Cost:** underwater sensors are expensive devices
  - more complex underwater transceivers
  - protection needed in the extreme underwater environment
- **Deployment:** more sparse, due to the cost involved
- **Power:** more power needed due to higher distances and to more complex signal processing at the receivers
- **Memory:** higher data caching as underwater channel may be intermittent
- **Spatial Correlation:** unlikely due to the higher distance among sensors.

Application scenarios

- **Ocean Sampling Networks:** Networks of sensors and AUVs observe and predict characteristics of oceanic environment
- **Environmental Monitoring:** pollution monitoring (chemical, biological, etc.), monitoring of ocean currents and winds, improved weather forecast, detecting climate change, understanding and predicting the effect of human activities on marine ecosystems, etc
- **Disaster Prevention:** measure seismic activity from remote locations and provide tsunami warnings to coastal areas
- **Assisted Navigation.** locate dangerous rocks or shoals in shallow waters, mooring positions, submerged wrecks, etc.
- **Distributed Tactical Surveillance:** monitor areas for surveillance, reconnaissance, targeting & intrusion detection
- **Mine Reconnaissance.** rapid environmental assessment and detect mine like objects

Acoustic propagation

- **Path loss**
  - **Attenuation.** Absorption, scattering an reverberation (rough ocean surface and bottom), refraction, and dispersion (displacement of reflection point by wind on surface) and depth
  - **Geometric Spreading**. increases with propagation distance and is independent of frequency
    - spherical (omni-directional point source)
    - cylindrical (horizontal radiation only).
- **Noise**
  - **Man made noise.** machinery noise (pumps, reduction gears, power plants, etc.), and shipping activity (hull fouling, animal life on hull, cavitation), especially in areas encumbered with heavy vessel traffic
  - **Ambient Noise.** related to hydrodynamics (movement of water including tides, current, storms, wind, rain, etc.), seismic and biological phenomena.

Acoustic propagation (cont)

- •**Multi-path**
  - severe degradation - Inter-Symbol Interference
  - depends on link configuration - Vertical channels: little time dispersion, horizontal channels: extremely long multi-path spreads
  - strong function of depth and the distance between transmitter and receiver
- **High delay and delay variance**
  - five orders of magnitude lower than in radio channel (0.67 s/km)
    - can reduce the throughput of the system considerably
  - very high delay variance is even more harmful
    - prevents from accurately estimating the round trip time (RTT), which is the key parameter for many common communication protocols

Acoustic propagation (cont)

- **Doppler spread**
  - The Doppler frequency spread can be significant: transmissions at a high data rate cause many adjacent symbols to interfere at receiver, requiring sophisticated signal processing to deal with the generated ISI
  - The Doppler spreading generates: i) a simple frequency translation, which is relatively easy for a receiver to compensate for; ii) a continuous spreading of frequencies, which constitutes a non-shifted signal, which is more difficult for a receiver to compensate for.
  - If a channel has a Doppler spread with bandwidth B and a signal has symbol duration T, then there are approximately BT uncorrelated samples of its complex envelope. When BT is much less than unity, channel is said to be underspread and effects of Doppler fading can be ignored, while, if greater than unity, it is overspread

Challenges

- Proactive routing protocols - large signalling overhead to maintain routes
- Reactive protocols) - higher latency and source induced flooding
- Geographic routing is promising
  - Localization is harder - no GPS, ocean currents move sensors and beacons, floors rugged

Approaches: Efficiency and packet size

- Channel efficiency is extremely poor
- Efficiency drops of steeply with distance
  - Forward error correction (adding redundancy helps)
  - Smaller packet size helps
  - Train of small packets
  - Train of repeated packets to avoid round trip
- Routing for delay sensitive (earliest deadline first scheduling) and delay in-sensitive applications
- Evaluated using simulation models - much work is needed to validate these underwater