Environmental-friendly underwater acoustic communications and networks

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Q: how do we perform underwater wireless communications that are not harmful/”pollute” the environment?

A1: we don’t know.

A2: we study the acoustic environment, the impact and then we try adapt.
The environmental challenge


■ Define “good environmental status”: the marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive

■ What is being done?
  ● AlfaSentral platform (Norway): plankton, benthic fauna, fish, marine mammals, seabirds, fishing activity, conservation areas and species
  ● 25 MEuro contract Statoil - Kongsberg

(from Statoil web site)
The technological challenge

■ “pre-sal” technological challenge (Petrobras, Brazil)
  - reservoir geological and seismic characterization
  - CO2 corrosion and wellbore fractures
  - large pipe (18”) in 2200 m water depth
  - long range to shore

■ The Arctic challenge ahead
The integrated vision

Underwater wireless communications is an enabling technology for integrating critical infrastructure protection and environmental monitoring networks

(from UAN project, FP7 # 225669)
Timeline (1)

Environmental-friendly ucomms and networks

- First Ucomms experiment (Intifante'98)
- Channel time spread time window optimization (Intifante'00)
- Tx/Rx positioning compensation (MREA'03/04)
- Surface motion compensation (UAB'07, Calcom'10)
- UA - Network (UAN'10/11)

...2013...
The matched filtering array

\[ y(t) = g(t) * s(t) + n(t) \]

- matched filter (MF)
  \[ h(t) = s(-t) \]
- matched field proc. (MFP)
  \[ h(t) = (g * s)(-t) \]
- virtual Time reversal (vTRM)
  \[ h(t) = y_t(-t) \]
Timeline (2)

- 1998: First Ucomms experiment (Intifante'98)
- 2000: Channel time spread time window optimization (Intifante'00)
- 2002: Tx/Rx positioning compensation (MREA'03/04)
- 2003/04:UA - Network (UAN'10/11)
- 2007: Surface motion compensation (UAB'07, Calcom'10)
- 2010:...
- 2011/12:...
- 2013:...

Environmental friendly
Time window selection for pTR

INTIFANTE’00 sea trial, Setúbal (Portugal)
station - 800 m

- 16hyd, 4m spacing VLA
- band 3.6 kHz
Timeline (3)

- Channel time spread time window optimization (Intifante'00)
- UA - Network (UAN'10/11)
- Environmental friendly

- First Ucomms experiment (Intifante'98)
- Tx/Rx positioning compensation (MREA'03/04)
- Surface motion compensation (UAB'07, Calcom'10)

...2013...
MREA’04, Setúbal (Portugal): $f_c = 3.6$ kHz, 2PSK, 400 symb/s
Geometric variability challenge (3)

UAN10, Pianosa (Italy): variable $f_c$, nPSK, SD, SR

pTR + DFE
No frequency shift

With frequency shift

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Environmental-friendly ucomms and networks
Timeline (4)

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Environmental variability challenge

- BPSK
- Carrier 6.25 kHz
- 1000 bits/s
- $50 \times 0.1$ s chirps for channel estimation
- 100 s data packets

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Environmental-friendly ucomms and networks
Timeline (5)

- First Ucomms experiment (Intifante'98)
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- UA - Network (UAN'10/11)
- Environmental friendly
- ...2013...
How to mitigate channel variability effects:

1. predict communication performance based on actual environmental conditions

2. adapt network node position for optimized ucom performance (or to establish connection to remote nodes)

3. simpler nodes (fixed/mobile) means less autonomy and processing power

4. concentrate complexity
   - take advantage of channel diversity
   - introduce noise / array gain
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Environmental-friendly ucomms and networks
The networking challenge

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5 Kongsberg cNode Mini Transponder

**Networking mode**
- node discovery
- multirate Cymbal protocol
- multihop

**Transparent mode**
- network inhibition
- node to VLA transmission
- nPSK modulated sequences
System complexity vs. channel capacity

- gateway: complex master node
- slave nodes
  - Folaga mobile nodes
  - fixed nodes with environmental sensors
### Network components

- **STU**: master node (AP)
- **MNx**: mobile nodes
- **FNOx**: fixed nodes
- **MOOS**: middleware data base
- **C2**: control and command

### Network layers:

- **Bi-SISO**: bidirectional modem
- **Uni-SIMO**: unidirectional modem
- **PPP-IP**: IP layer
- **MOOS-client**: message communication over IP

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Environmental-friendly ucomms and networks
UAN11 sea trial, Strindfjorden (Trondheim, Norway) (1)
UAN11 sea trial, Strindfjorden (Trondheim, Norway) (2)

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Environmental-friendly ucomms and networks
Networking issues: master to fixed node 2

- Data rate 200 bps, occasionally 500 bps
- Up to 500s packet delay
- 40 and 42% data loss
- Most data was received with delays 3 to 20s
- Packets actually received, but link broken for the ack
Network transparent signals: FS-pTR + DFE

**Folaga 2** May 27, 2011, MSE = -15.7, BER=0

**R/V Gunnerus (moving):** May 27, 2011, MSE = -14.8, BER=0
1. Demonstration at sea of a full network up to the application layer.
2. Concurrent SISO (networking) and SIMO (network transparent) messaging.
3. Control and command running for several hours in an intruder interception task.
4. Grab environmental information from nodes.
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Environmental-friendly ucomms and networks
1. Demonstration at sea of a full network up to the application layer
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4. Gathering environmental information from nodes
characterize the coastal ecosystem soundscape
  - time periodicities and variability: day/night, lunar cycles, year, season...
  - correlations with other ocean effects: tidal variations, temperature variability, current system,...
  - frequency band: effective at least in 1 - 10 kHz*
  - correlation and statistics in time and space

 correlate with species
  - abundance, activity, health, location
  - type (resonating sea urchin, snapping shrimp, coquille St. Jacques, "breathing" sea grass, ...)

 usage for ucomms?
  - correlate with ucomms performance
  - adapt levels, levels, biological noise becomes biological (interference) signal

* work by Di Iorio, Gervaise, Chauvaud et al. from GiPSA-Lab, LEMAR, and others
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Underwater Acoustic Network\(^1\) (2008-2011)
www.ua-net.eu

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