Marine environmental surveillance using miniature sensors modules

Jens M. Hovem - SINTEF-ICT

Sensorcomm2011-Nice, France August 2011

Abstract

Progress in electronics and computers has opened new possibilities for marine environmental monitoring and surveillance. This note presents new concepts for marine environmental monitoring and surveillance based on networks of autonomous sensors interconnected by wireless acoustic communication. The novelty of the concept is the use of a large number of small and inexpensive sensor modules that can be deployed rapidly in situations to cover a large volume of water in area and depth. This note proposes to carry out An introductory project is proposed to explore the feasibility of manufacturing small underwater acoustic devices that can be used as nodes in underwater acoustic sensor networks and as underwater acoustic identification (UAID) tags for identification, location and tracking of people and objects under water. The challenge is to design and manufacture the sensor modules to meet the required specifications to an acceptable price for mass production and utilization

1 Background and introduction

Traditionally ocean surveillance is accomplished with ships, aircraft, satellites and distributed sensor as oceanographic buoys, either moored or free drifting, (Figure 1a). These are generally very expensive units and especially useful in routine collection of information.

Progress in underwater acoustic wireless communication systems technology, coupled with modern sensor network technology, has open up for new possibilities in ocean surveillance and monitoring. Figure 1b illustrates a recently developed underwater network system applied for monitoring an underwater production facility. Such systems are now coming into commercial use, but only for high-cost special application using only a few nodes.

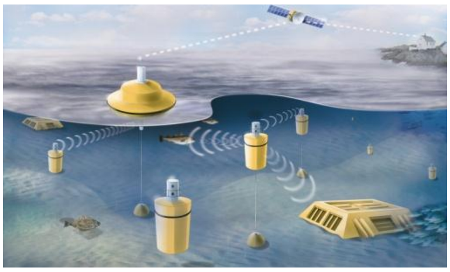
(a)  (b) 

Figure 1 State-of-the- art ocean monitoring and surveillance using (left) ships, underwater vehicles, aircrafts and satellite and (right) model network for underwater production monitoring and control.

2 The concept and its novelty

The new concept is to use a large number of inexpensive sensors modules spread out to cover the area of interest. A possible, but relevant scenario, illustrated in Figure 2, is in emergency situations, for instance leakage of a harmful or toxic substance from a ship or an offshore installation. In such instances rapid response is essential and we envisage dropping about 100 sensor modules over an area of 10 km x 10 km from helicopter. The modules, equipped with the relevant sensors, collect and send information to one or several master nodes for further transmission via cable and radio to an operation center. In such emergency situation, the operational lifetime is not required to be very long, maybe only a couple of weeks, and therefore the battery package may be quite small.

After use, the sensor can either be programmed to float to the surface for recovery or sink to the bottom. This requires the units to have a ballast system for weight and buoyancy control. The question whether the modules should be recovered or allowed to remain on the bottom is partly an environmental question that needs to be discussed further. This issue will also depend of the materials being used, especially the type of batteries, and the price of the units.

Another application parallels the radio frequency identification technology (RFID) to exchange data between a reader and an electronic tag attached to an object, for the identification and tracking. In the same way it is feasible to use underwater acoustic identification (UAID) tags for identification, location and tracking of people and objects under water

The proposed sensor module, shown in Figure 3, has the shape of a short cylinder with diameter of 2 cm and a length of 10-15 cm. The unit contains an acoustic modem for communication with other modules and a computer and various sensors. In addition there is a battery package and ballast system for weight and buoyancy control.

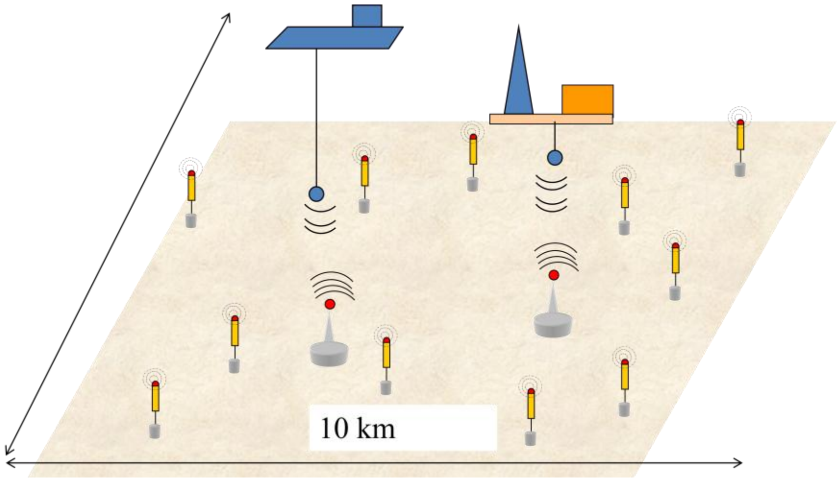


Figure 2 The concept of using a large number of inexpensive sensor modules for ad-hoc monitoring of an emergency situation

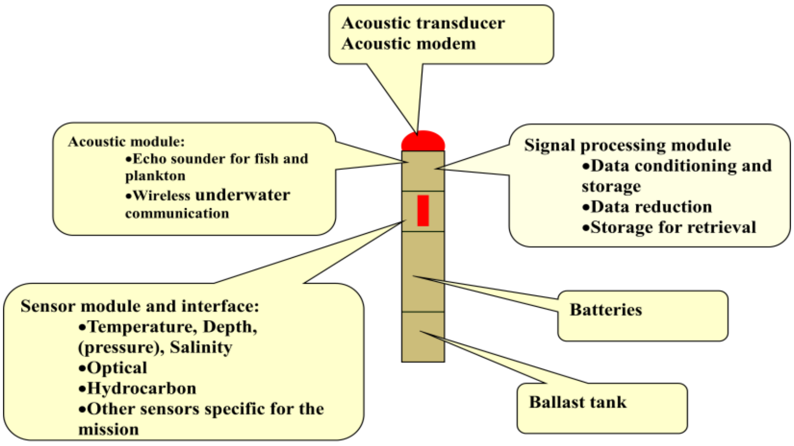


Figure 3 The generic sensor module

3 Physical description and design principles

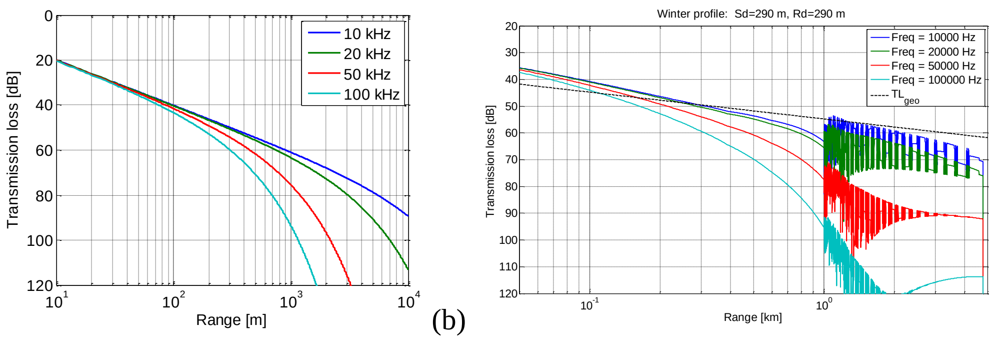
In the following the functionality and design principles for the sensor module are outlined.

3.1 The acoustic module

The acoustic frequency in the wireless communication systems should be higher than the frequency normally used for acoustic communication. The proposed carrier frequency is around 50 kHz with useful bandwidth of about 5 kHz. The transducer can be realized with a ceramic piezoelectric tube with a diameter of approximately 25 mm to match the diameter of the module.

The frequency dependence of acoustic absorption in saltwater this will limit the range to about 1000 m as shown in Figure 4a. This is also approximately the maximum achievable range between near-bottom mounted nodes as shown in Figure 4b. This limitation is caused by upward refraction at deeper depths and is a general feature of propagation in deep water below the thermocline. Another advantage of higher frequency is to limit the interference from other modules at longer distances.

The basic acoustic module is also the basis for underwater acoustic identification (UAID) tags.

(a)


(b)

Figure 4 Transmission loss in dB as function of range. (a): Free-space propagation with spherical spreading and frequency dependent absorption. (b) Real situation for communication between two near-bottom mounted nodes

3.2 Electronic and signal processing unit

Choice of modulation scheme depends on the specifications particularly the transmitted source level and required of computer processing capability. Low power consumption is essential.

3.3 The communication network

The communication network must be capable of handling multi-hop transmission of information with adaptive routing. Security and reliability is more important than high data rates. The tags and the nodes must have the capability of adapting to varying multipath interference.

3.4 Sensor module

The sensor module should be designed on the principles of plug-and-play with a flexible interface enabling the module to be equipped with different sensors, depending on the mission. Some of these sensor types are indicated in Figure 3. However, the development of new sensor technology is outside the scope of this proposal.

4 Conclusion

Advancement in the field of underwater acoustic communication for transmission and distribution of data has increased significantly in recent years. The concept of underwater network with sensors interconnected with wireless acoustic networks and is well established is therefore technical feasible. The uncertainty lies in the development and manufacturing of the sensor modules to an affordable price or mass production and use.

References

Faugstadmo, J.E., M. Pettersen, J. M Hovem, A. Lie, and T.A. Reinen ”Underwater Wireless Sensor Network” 2010 *Fourth International Conference on Sensor Technologies and Applications 18-25 July 2010 Venice/Mestre, Italy.*
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New concept for marine environmental surveillance using miniature sensor modules

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Sensorcomm2011 Nice August 2011

NNN-New nerve system for Northern Waters

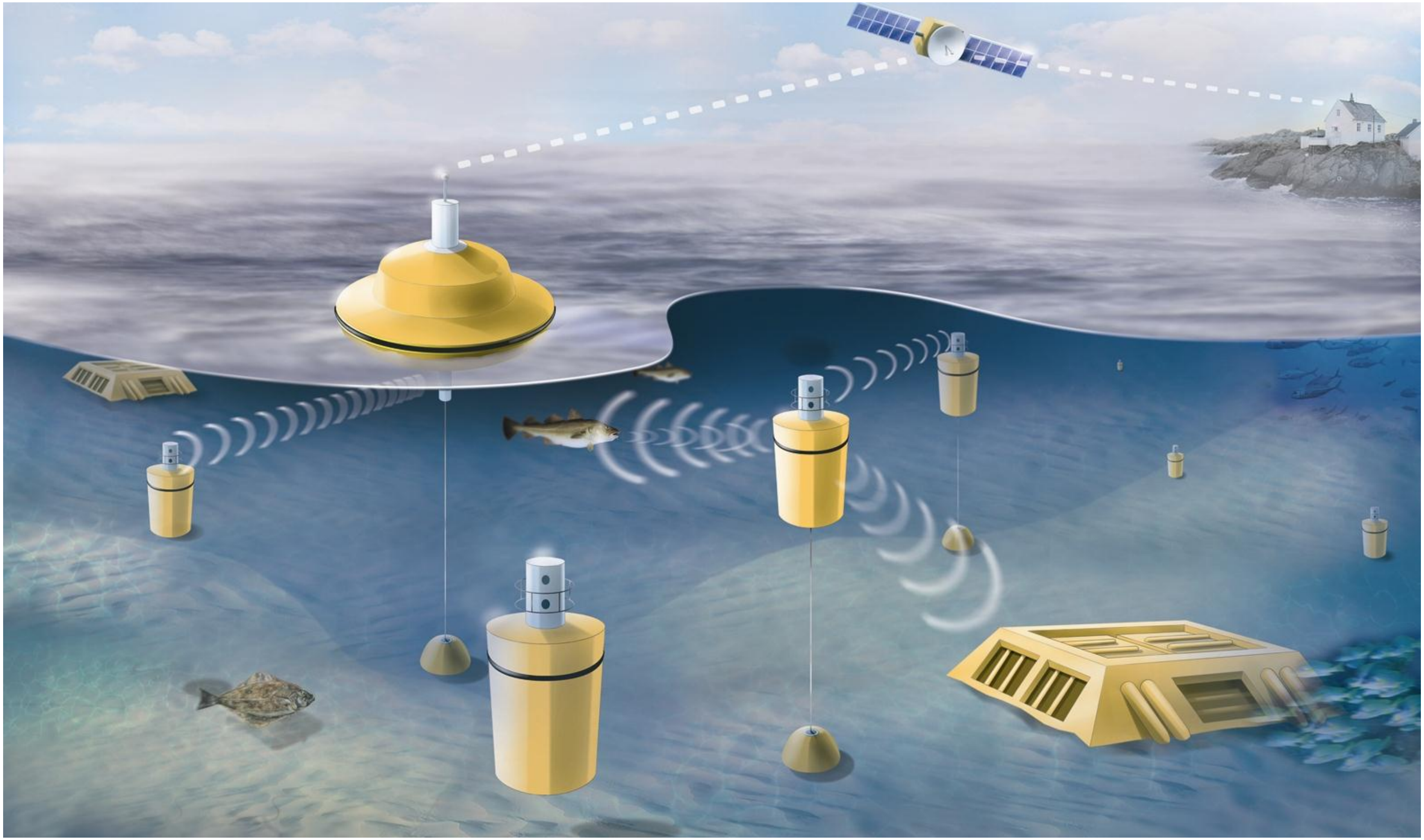
New possibilities in marine science
What needs to be done?

- Recent developments in information technology and communication technology give new possibilities for observation and surveillance of the marine ecosystem.

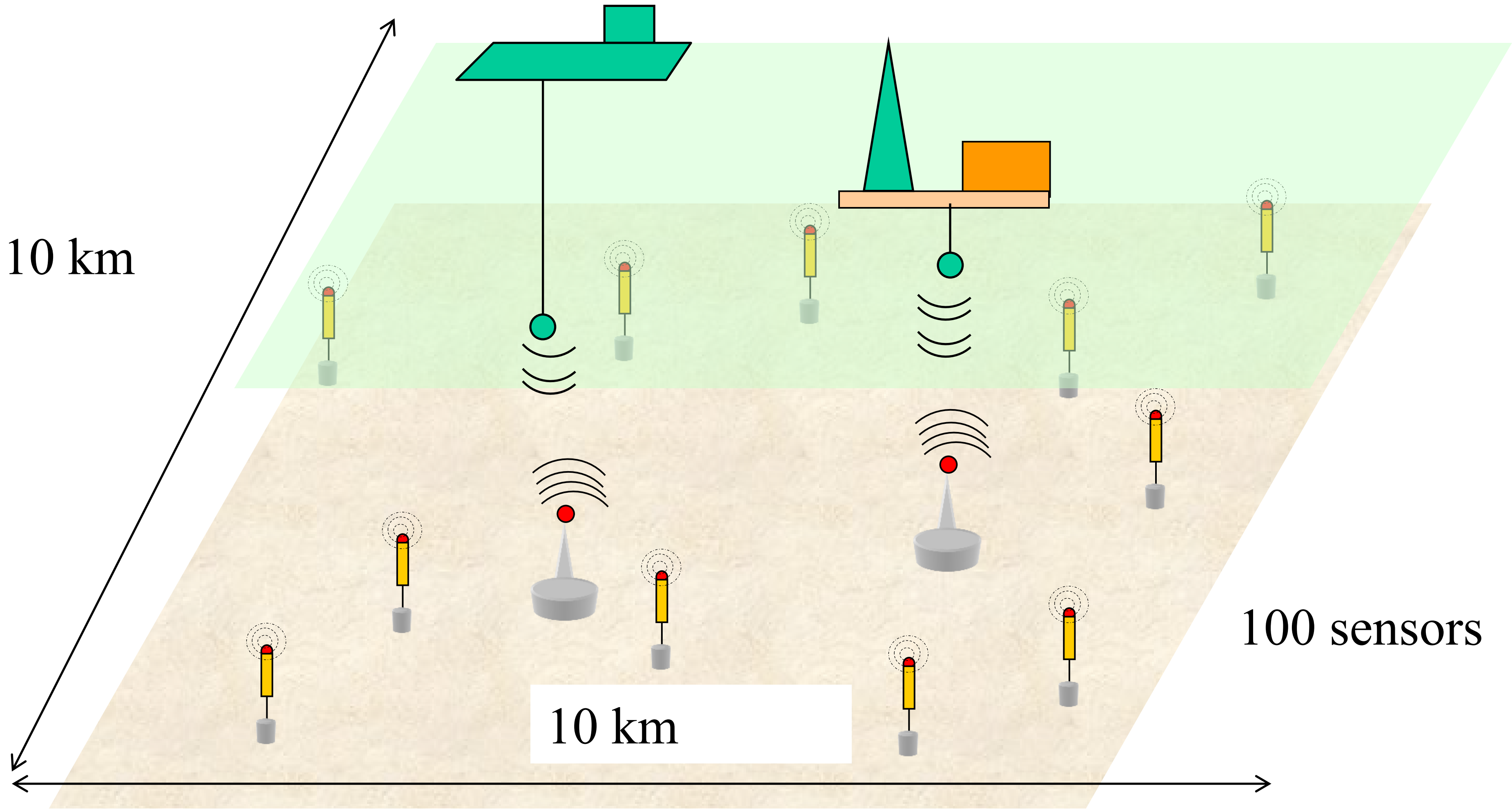
- The challenge is to make use of new sensor and communication technology in marine observation systems.

- R&D objective: Adapt new ICT technology for observation and surveillance of the marine ecosystem.

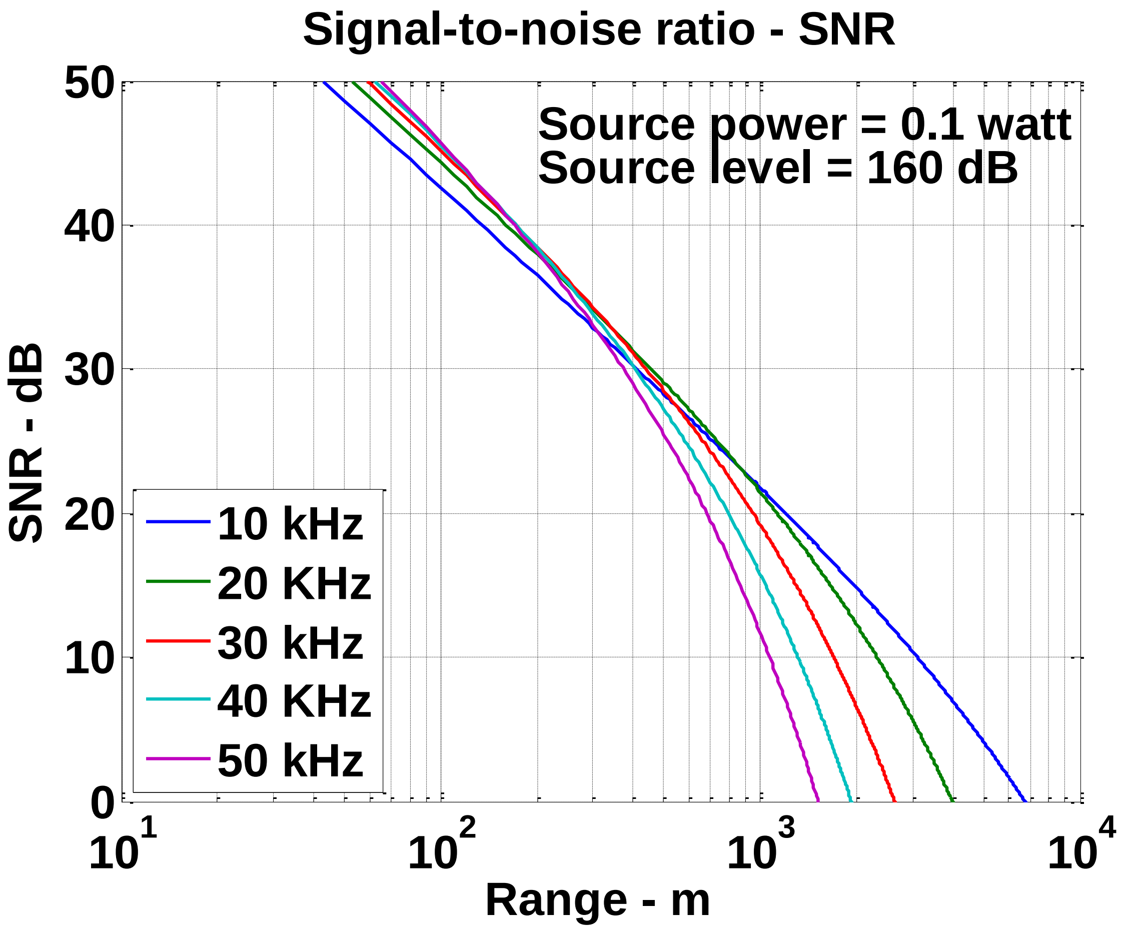
Sensor network



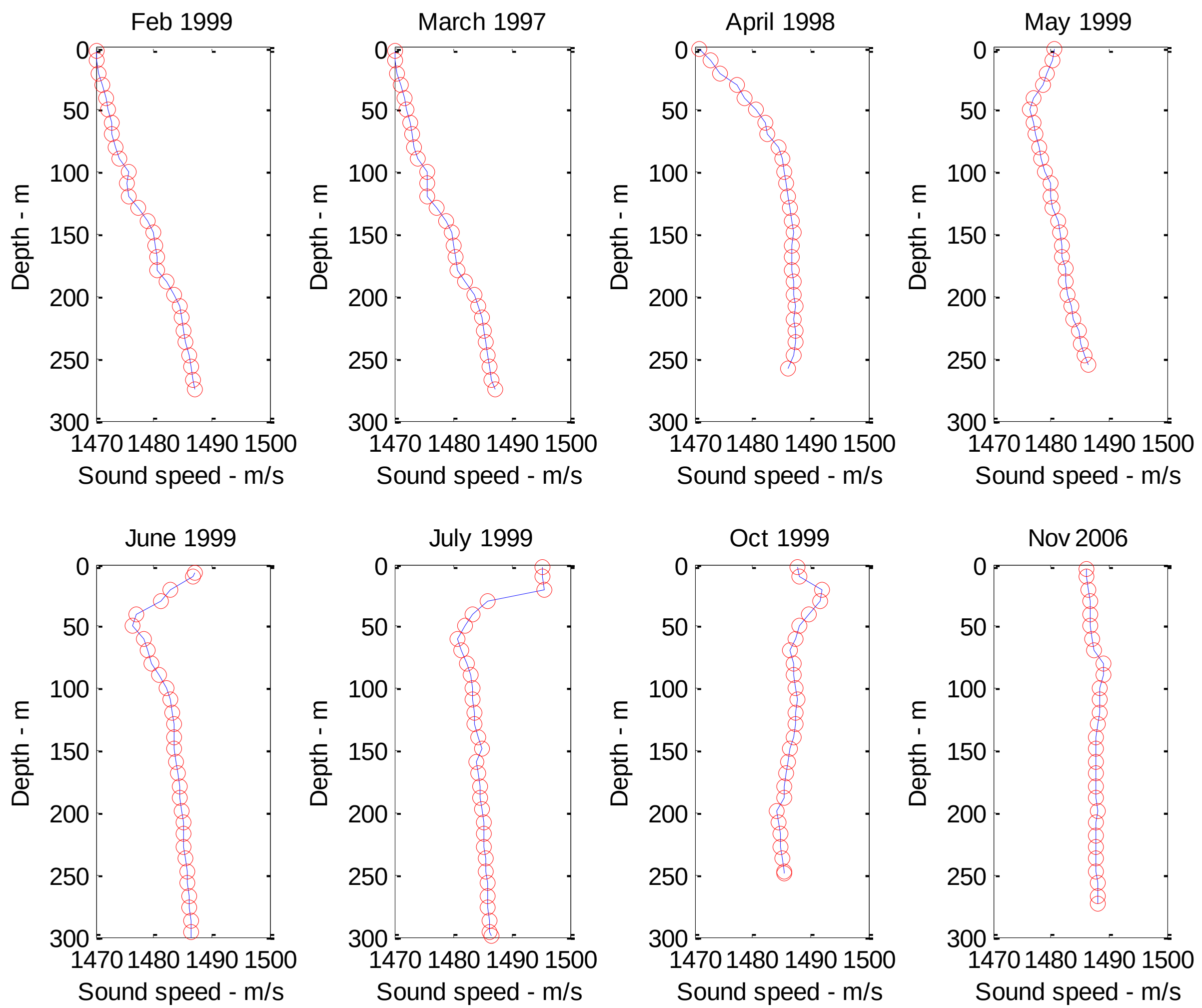
Sensor network-concept



Signal-to-noise- ratio



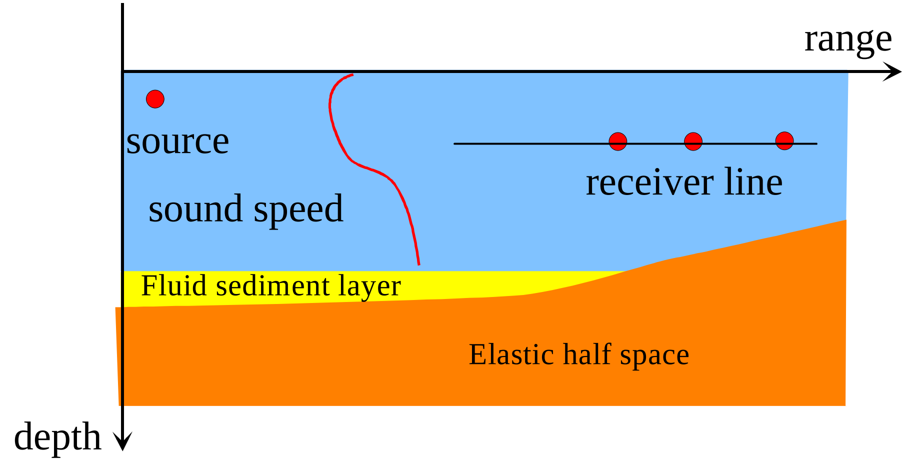
Sound speed profiles - Haltenbanken

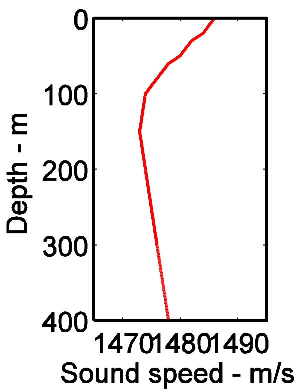


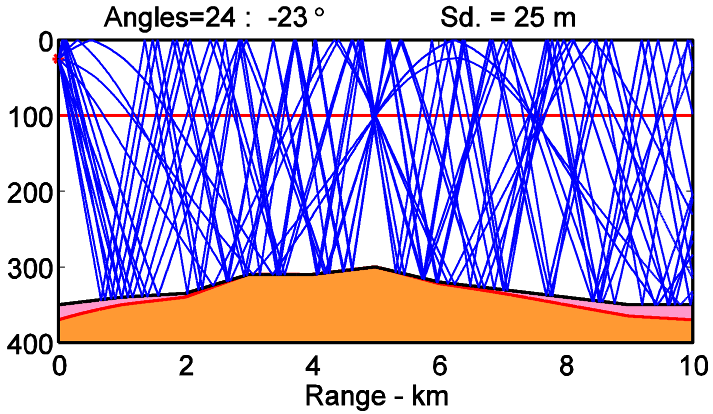
Modeling and understanding of the acoustic propagation condition

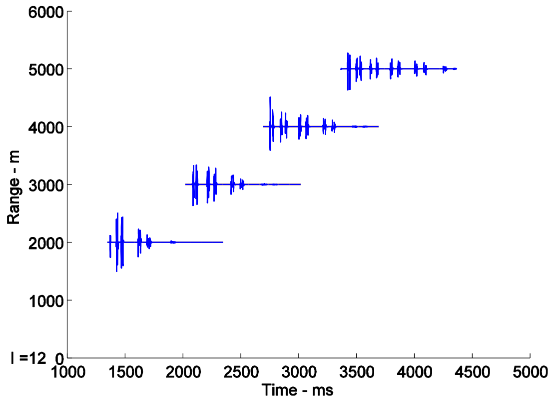
1. Computes the received field from a source to a number oft receivers located on a horizontal line. The bottom can be a fluid sedimentary layer over an elastic half space and both can be range dependent.

1. Coherently additions of all multi-path contributions to produce broad band time and frequency field descriptions.



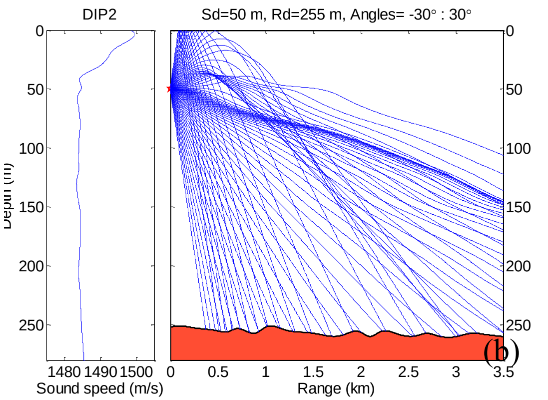




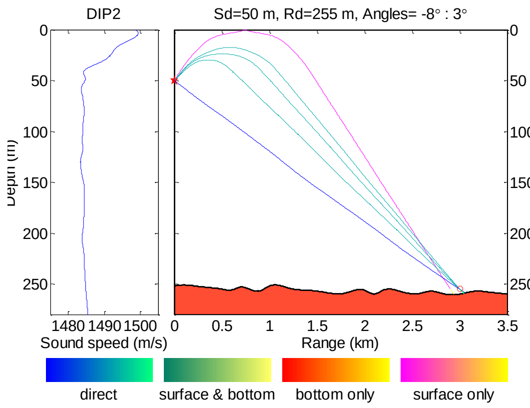


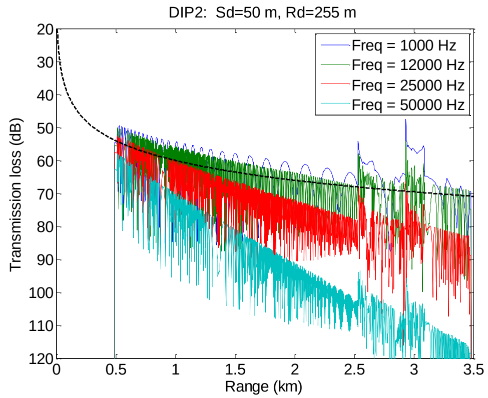
PlaneRay modeling

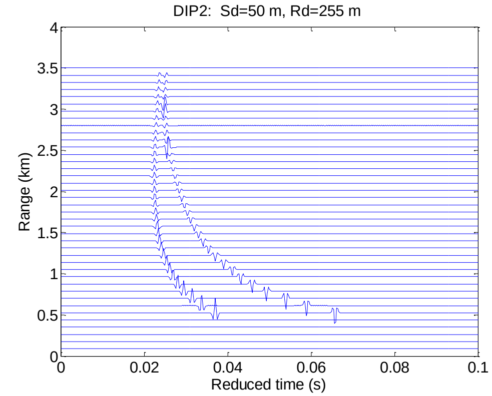
(a)



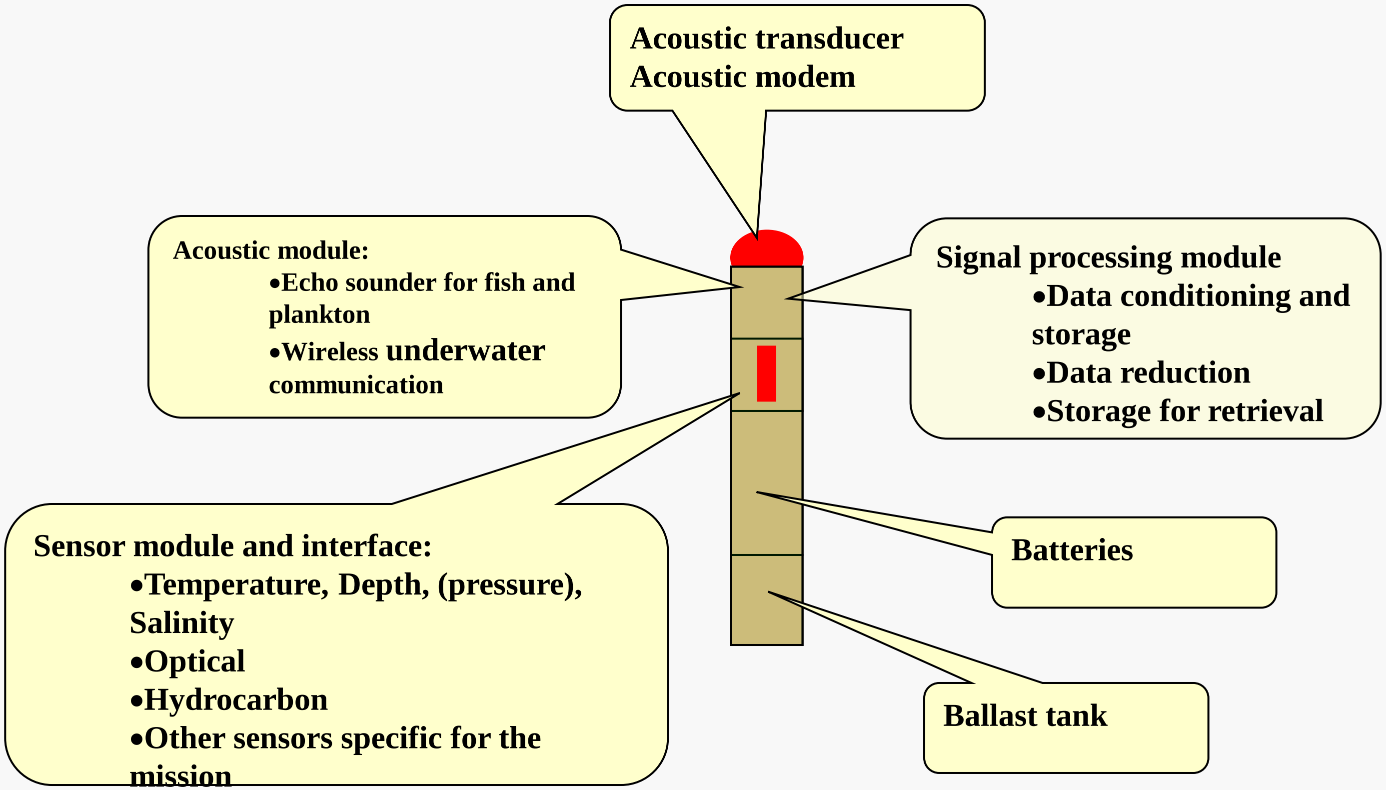
(b)







Generic Marine Sensor Unit (GMSU)



Conclusions

- Advancement in the field of underwater acoustic communication for transmission and distribution of data has increased significantly in recent years.
- The technology of underwater network with sensors interconnected with wireless acoustic networks and is well established.*
- The concept of using a large number of in expensive sensors for ad-hoc surveillance and monitoring the ocean environment is therefore technical feasible.
- The uncertainty lies in the development and manufacturing of the sensor modules to an affordable price or mass production and use.

* Faugstadmo, J.E., M. Pettersen, J. M Hovem, A. Lie, and T.A. Reinen ”Underwater Wireless Sensor Network” 2010 *Fourth International Conference on Sensor Technologies and Applications 18-25 July 2010 Venice/Mestre, Italy.*
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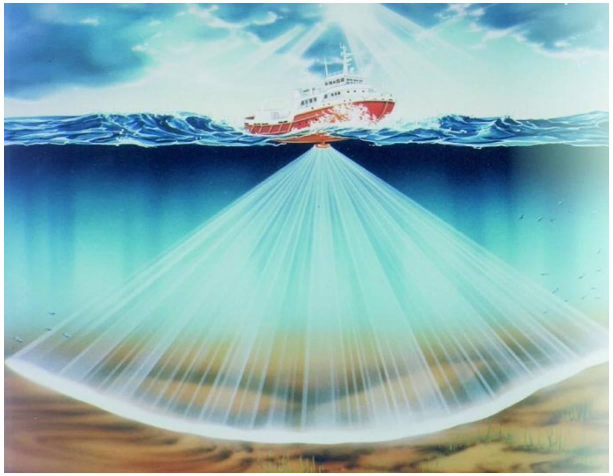

Marine Acoustics – The Physics of Sound in Underwater Environments Jens M. Hovem

ISBN 9780932146656

- Peninsula Publishing, a publishing company in Los Altos Hills, California, USA specializing in books in underwater acoustics, will be publishing the new, authoritative book,
- "Marine Acoustics the Physics of Sound in Underwater Environments “ by Dr. Jens M. Hovem, in September of this year.

The book provides an insightful introduction in to the use of underwater acoustics for the detection and classification of submarines, mines, fish and undersea life; mapping the ocean bottom; underwater exploration for oil and geologic characteristics, and ocean mining; characterizing oceanographic conditions of the sea; and communications using underwater sound. The book addresses technology of sonar systems, transducers and performance analysis. "Marine Acoustics" provides a strong foundation of theory and will make an excellent college textbook.

SENSOR NETWORKS ON YARN MASS PARAMETERIZATION METHODS – A CHALLENGE

Image source: www.recet.pt
(access in august 2011)

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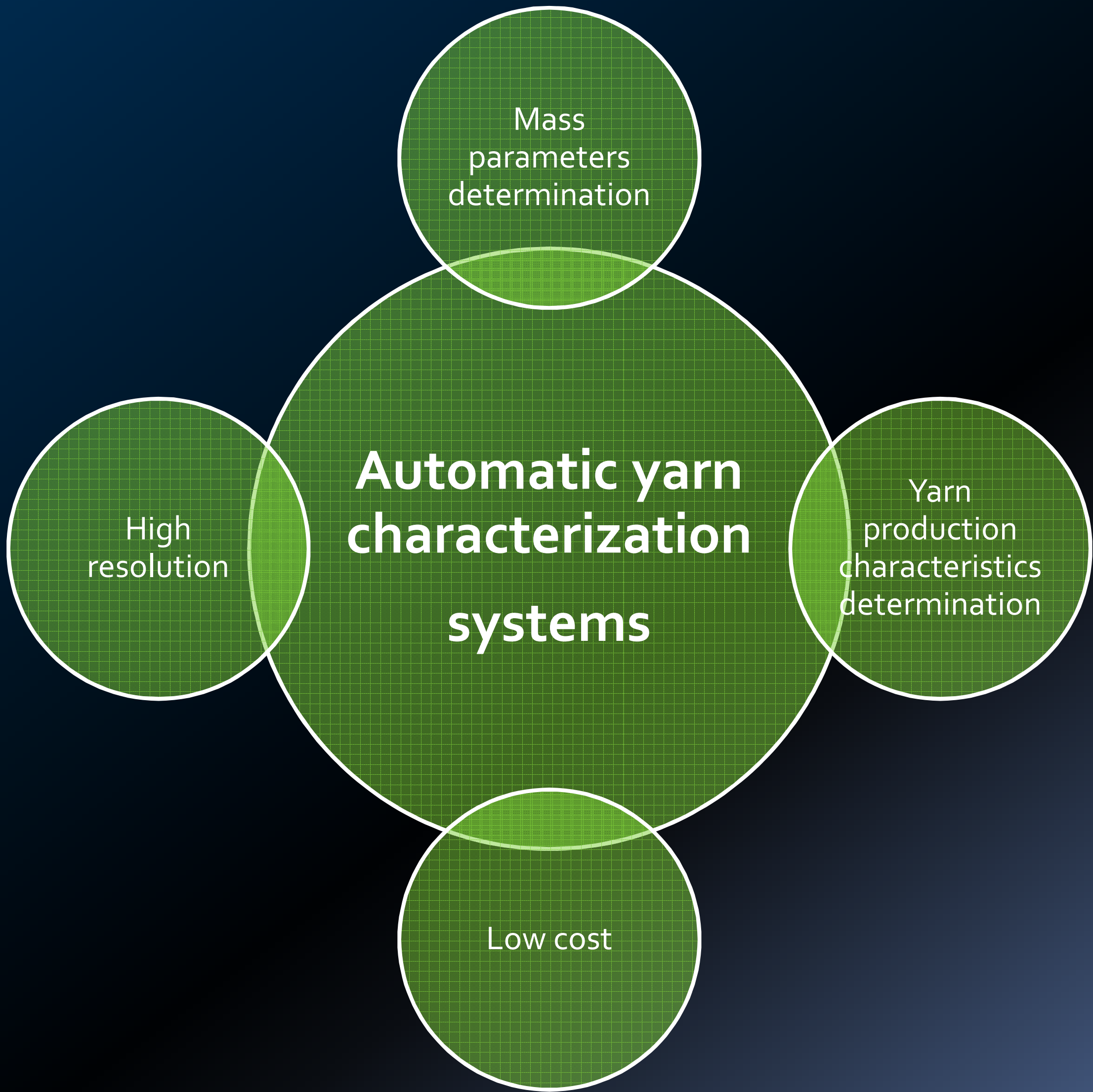
UNIVERSITY OF MINHO (UM) – PORTUGAL

Summary

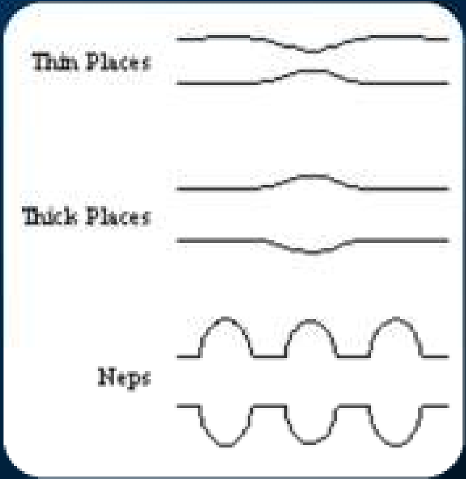
- Industry Necessities
- Mass Parameters
- Production Parameters
- Traditional Equipment
- YSQ / Constraints
- A Partial Approach
- The Full Approach Challenge
- Motivation

Industry Necessities

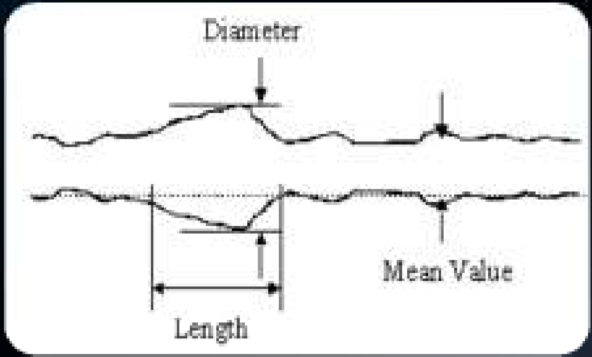


Mass Parameters

Irregularities

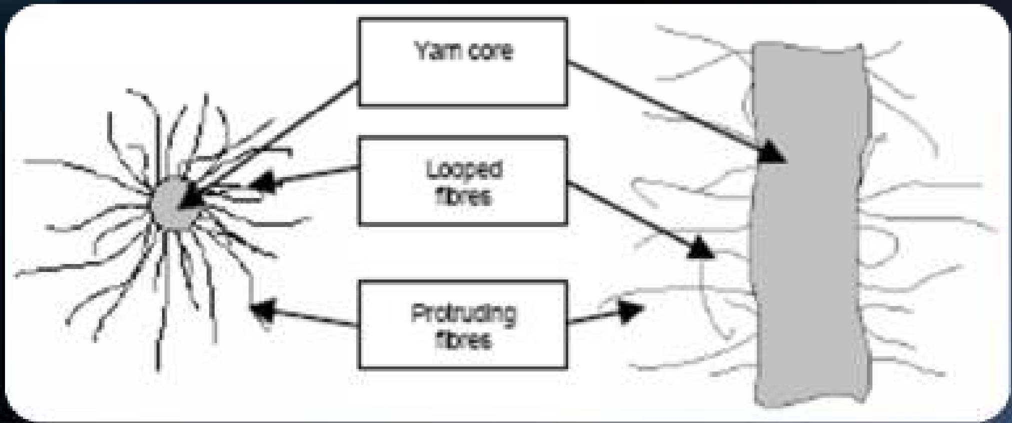


Diameter/Mass



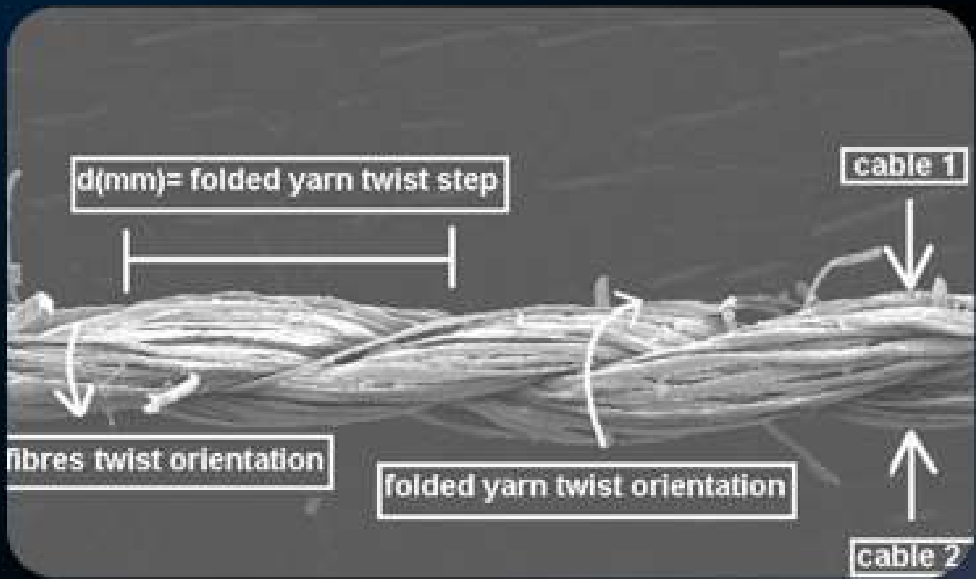
d(mm) = 0.060sqrt(g/km)

Hairiness



Production Parameters

Twist step, orientation, number of cables



Traditional Equipment

- Uster Tester 5

Image source: www.uster.com (access in august 2011)

- Zweigle Multitester

Image source: www.mezgerinc.com access in august 2011)

High cost, volume and weight

Limited resolution and precision

Complex measurement hardware

YSQ – The Developed Prototype (1)

Supress the drawbacks of the traditional equipment

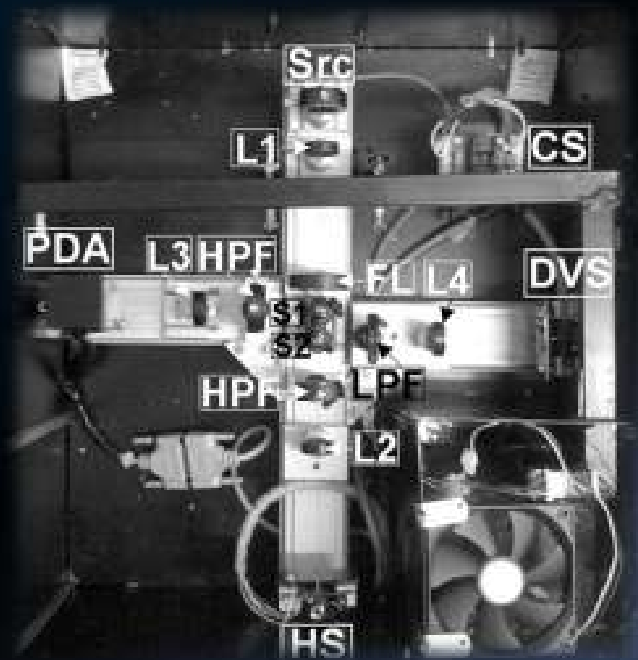
55cmX50cmX25cm

≈30 kg

YSQ – The Developed Prototype (2)

Yarn Production Characteristics Measurement

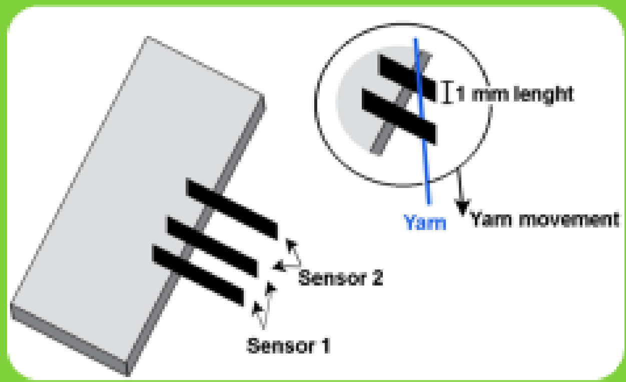
Yarn Mass Parameters Measurement



YSQ - Technological Approaches (1)

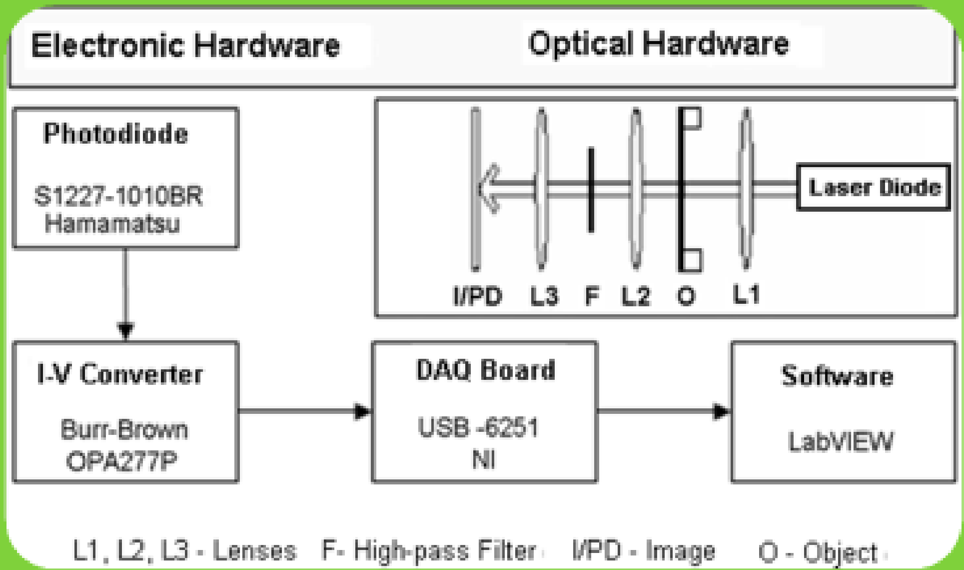
Direct Measurement of Yarn Mass Variation

- **Differential** configuration of **1mm** parallel plate capacitive sensors
  - Superior **stability**
  - Lower radiation dependence
  - Higher **precision** (20.8 aF for a 57 tex -g/km yarn)



YSQ - Technological Approaches (2)

Yarn Hairiness Measurement



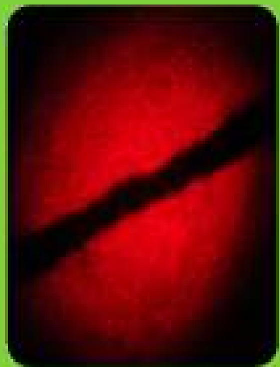
Example of an Image of Yarn Hairiness (I/PD)

YSQ - Technological Approaches (3)

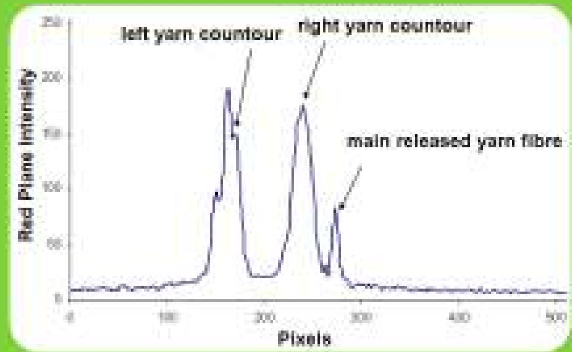
Yarn Diameter Measurement

Example of an Image for Measurement of Yarn Diameter with a Photodiode (a) and Measurement Result with PDA (b)

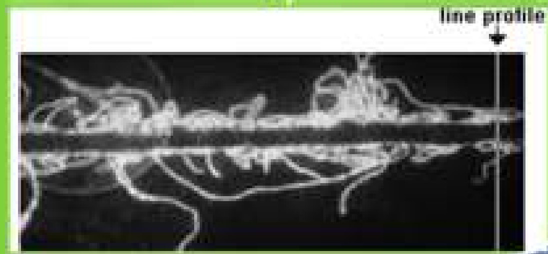
- **Low precision measurements:** photodiode (Fourier invertion: low-pass)
- **High precision** photodiode array (PDA) (High-pass filter)



a)



b)



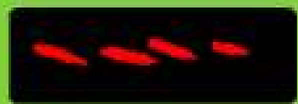
YSQ - Technological Approaches (4)

Yarn Production Characteristics Measurement – Image Processing (IP)

Example of a Yarn Image Obtained by the System

Spun yarn

Folded yarn



Measured Characteristics

- Number of cables
- Folded yarn step
- Fibres twist orientation
- Folded yarn orientation

Constraints

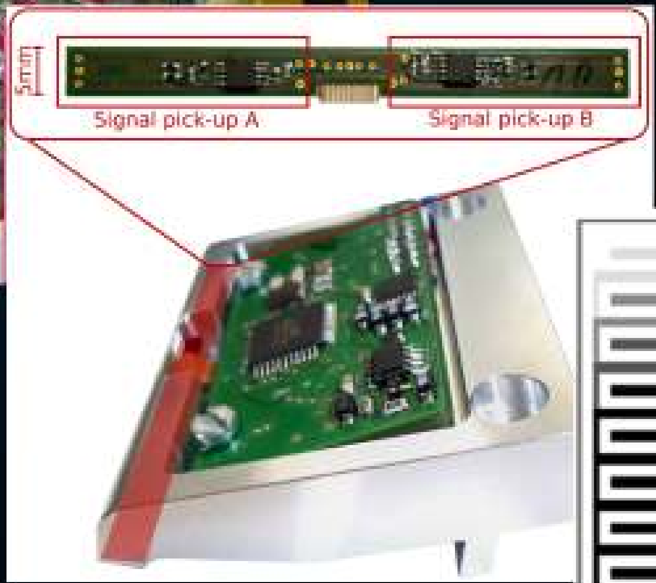
The YSQ and the Commercial Equipment **can not** be used in a sensor network of production systems:

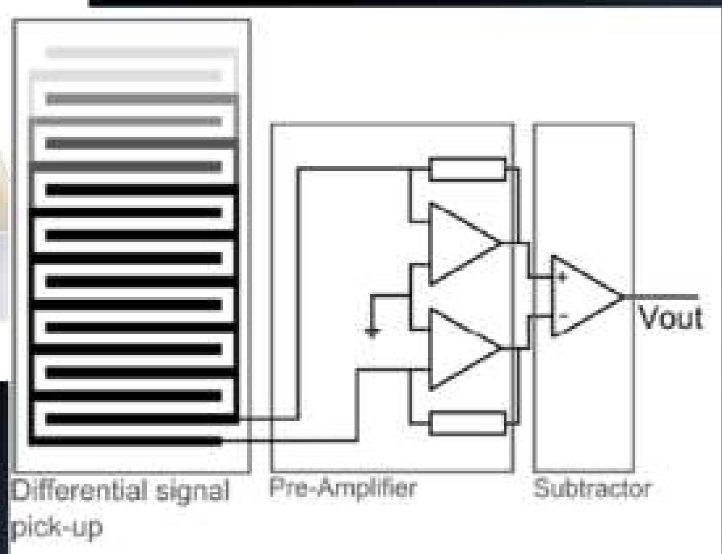
- Offline use/laboratory use
- High cost/ dimension

A Partial Approach – Sensor Network

Yarn Presence, Speed and Dust

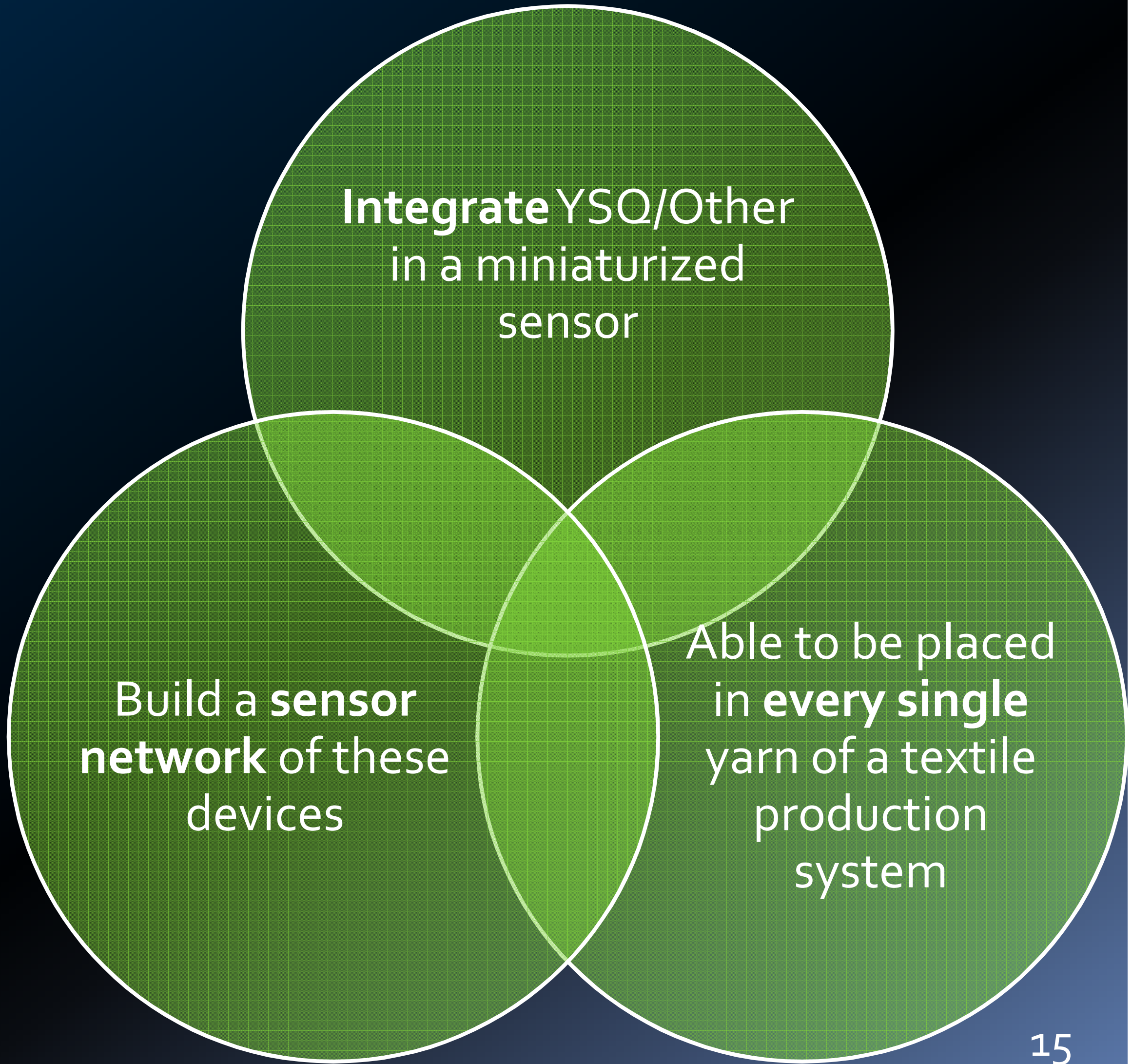
(Steffen Heinz et al. (2008))



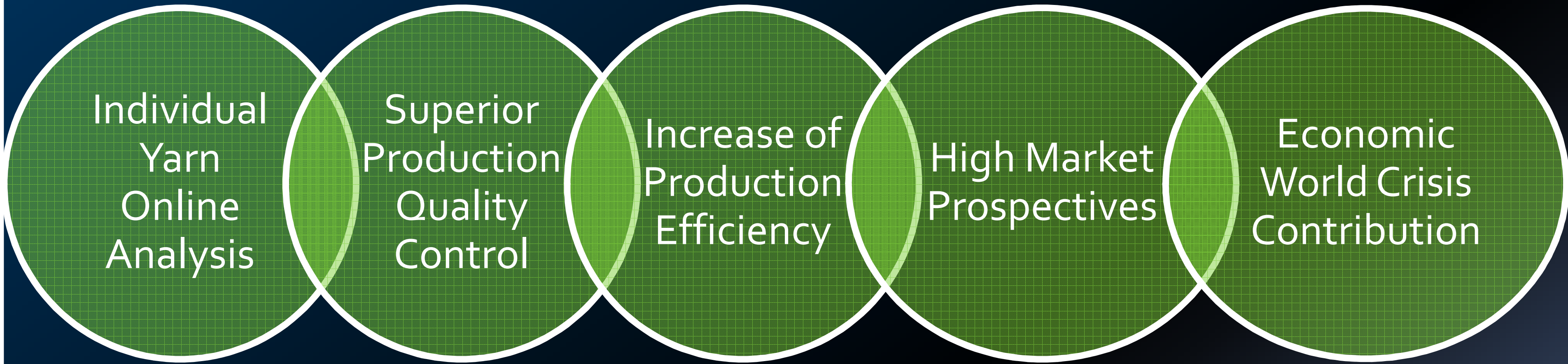


The Full Approach Challenge

Image source: www.recet.pt (access in august 2011)



Motivation


Individual Yarn Online Analysis
Superior Production Quality Control
Increase of Production Efficiency
High Market Prospectives
Economic World Crisis Contribution

SENSOR NETWORKS ON YARN MASS PARAMETERIZATION METHODS – A CHALLENGE

Thank you!

email: vcarvalho@dei.uminho.pt

Keynote Article: August 2004, Analytical Chemistry (ACS)

internet scale sensing

Dermot Diamond
Dublin City University
(Ireland)

Incredible advances in digital communications and computer power have profoundly changed our lives. One chemist shares his vision of the role of analytical science in the next communications revolution.

Digital communications networks are at the heart of modern society. The digitization of communications, the development of the Internet, and the availability of relatively inexpensive but powerful mobile computing technologies have established a global communications network capable of linking billions of people, places, and objects. Email can instantly transmit complex documents to multiple remote locations, and websites provide a platform for instantaneous notification, dissemination, and exchange of information globally. This technology is now pervasive, and those in research and business have multiple interactions with this digital world every day. However, this technology might simply be the foundation for the next wave of development that will provide a seamless interface between the real and digital worlds.

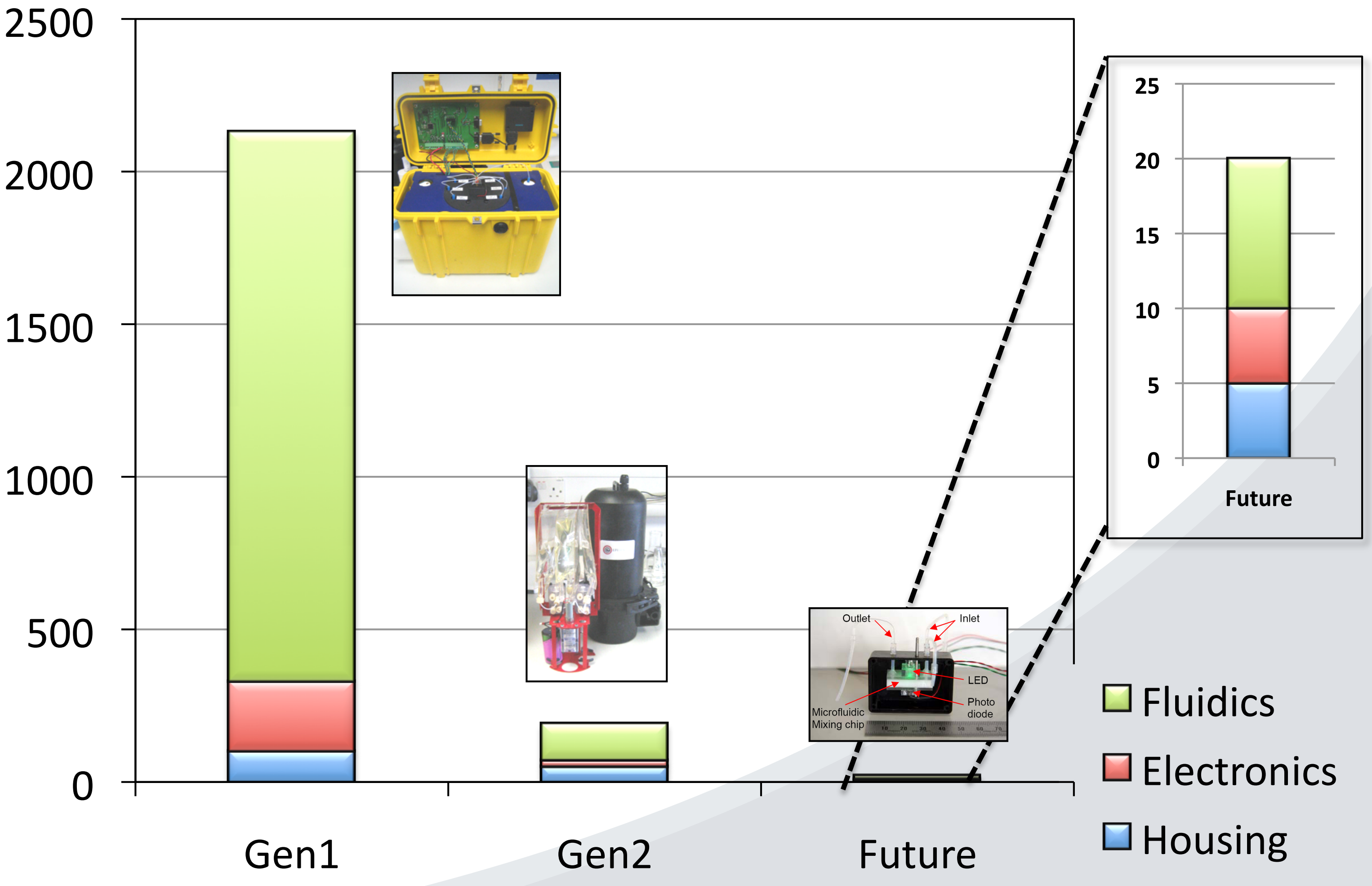
The crucial missing part in this scenario is the gateway through which these worlds will communicate: How can the digital world sense and respond to changes in the real world? Analytical scientists—particularly those working on chemical sensors, biosensors, and compact, autonomous instruments—are

Dermot Diamond, Anal. Chem., 76 (2004) 278A-286A
(Ron Ambrosio & Alex Morrow, IBM TJ Watson)

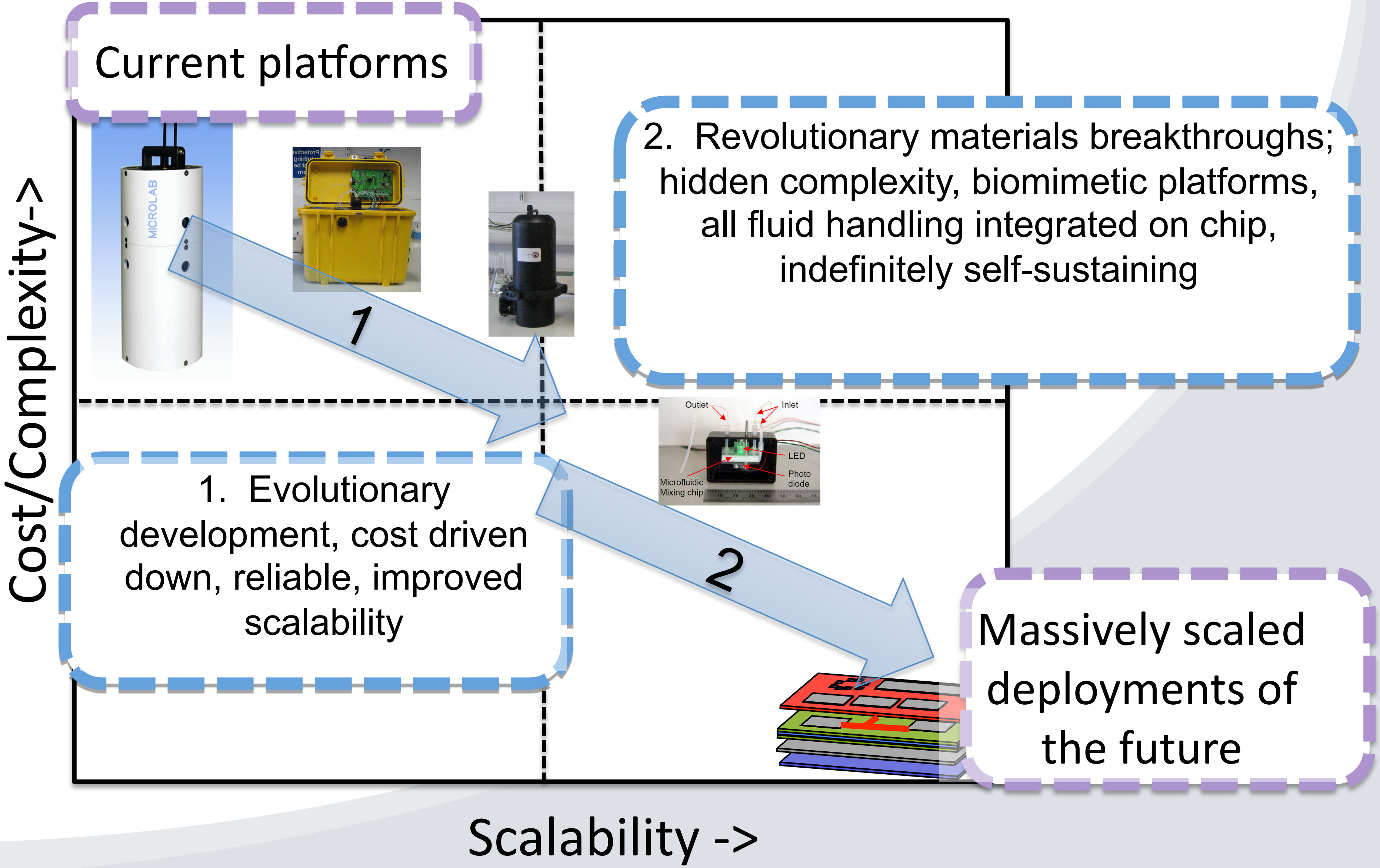
The key challenge for large scale environmental sensor deployments and for implantable sensors is the same:

How do we keep these sensing devices & systems functioning autonomously for long periods of time - at least months, ideally years, and, how do we do this at an acceptable unit cost?

Cost Comparison Analyser (€)



Achieving Scale-up



Challenges in Building Sensor Networks with Special Sensor Devices

Prof. Jerker Delsing
EISLAB
Luleå University of TEchnology

Interesting problem #1

- WSN platforms
  - Sensor HW
  - uP
  - SW
    - Evaluation
    - Communication
    - System integration
- Sensors HW are most often not designed with extreme low resources in mind like
  - Very low power resources
  - Very limited memory
  - Limited computing resources
  - Limited communication BW

Interesting problem #2

- WSN platforms and wireless power
  - New technologies for energy harvesting
  - Possible to produce in large volume to “no” cost

Interesting problem #3

- Integration of a WSN sensor to a system
  - SOA technology
    - Protocols OPC-UA, DPWS, CoAP
    - Engineering tools
    - Management tools
  - Sensor description semantics -
    - XML formats
    - Every area of application now defines their own “standard”