KEY WIRELESS NETWORKING TECHNOLOGIES IN THE NEXT DECADE

(LATEST INITIATIVES AT NSF & DoD in the USA)

I. F. AKYILDIZ

Broadband & Wireless Networking Laboratory
School of Electrical and Computer Engineering
Georgia Institute of Technology
Tel: 404-894-5141; Fax: 404-894-7883
Email: ian@ece.gatech.edu
Web: http://www.ece.gatech.edu/research/labs/bwn

LATEST NSF INITIATIVES

The GENI (Global Environment for Networking Investigations)

* New architectures for PERVASIVE COMPUTING, mobile, wireless and sensor networks.
* Building new services and applications
* Deploying and validating

FIND (FUTURE INTERNET NETWORK DESIGN)

(Architecture, Mobile Wireless and Sensor Technologies)

LATEST DoD INITIATIVES

- Automated Wide-Area Network Configuration from High-Level Specifications
- Robust Self-Forming Human Networks: Making Organizations Work
- Modification of WiFi Communication Devices to Support the Urban Warrior
- Scalable Mobile Wireless Mesh Networks
- xG (Dynamic Spectrum Access) Cognitive Radio Networks
- CBMANET (Control Based Mobile Ad Hoc Networks)

KEY TECHNOLOGIES

- SENSOR & ACTOR NETWORKS
- xG WIRELESS SYSTEMS

  [DYNAMIC SPECTRUM ACCESS NETWORKS]

  COGNITIVE RADIO NETWORKS

KEY TECHNOLOGIES

- WiMAX
- WIRELESS MESH NETWORKS

I.F. Akyildiz and X. Wang,

"Wireless Mesh Networks; A Survey",
Computer Networks (Elsevier) Journal, March 2005.
Shorter version in

IEEE Communications Magazine, Sept. 2005.

FUTURE INTERNET

ALL OF THE ABOVE NETWORKS

CO-EXISTING IN A SEAMLESS WAY!!!

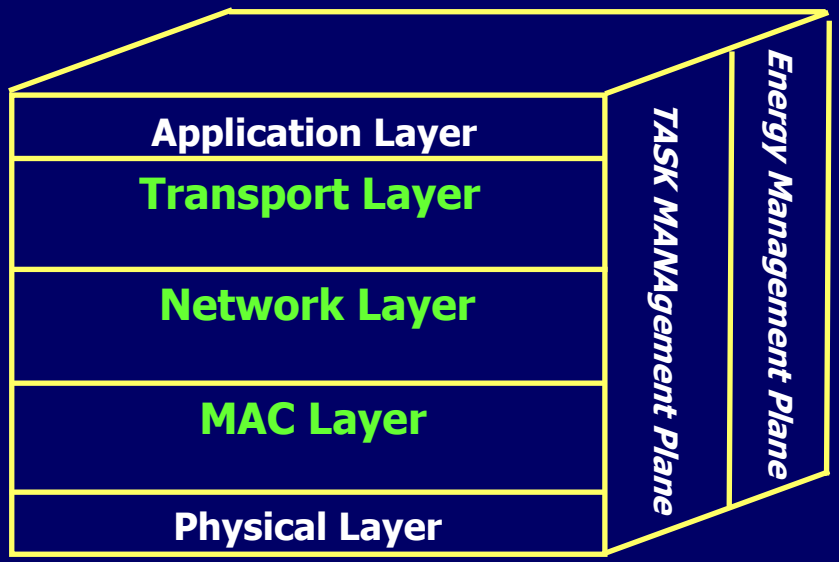
KEY TECHNOLOGIES

- SENSOR & ACTOR NETWORKS

- 6K Papers are written the last 5 years!!
- A PAPER WRITING RACE!!!
- A LOT OF EPSILONs!!!!!!

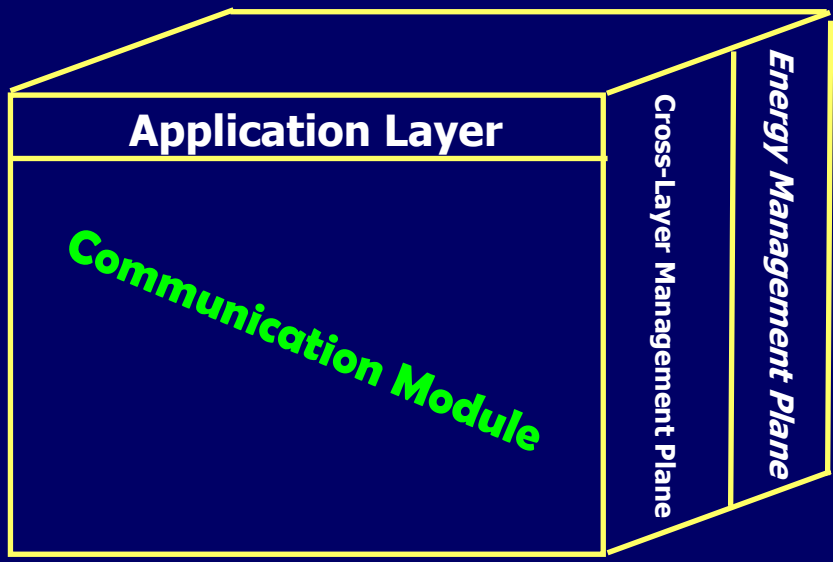
GRAND CHALLENGE 1:

raditional layered approach is not suitable for WSNs



Traditional Approach

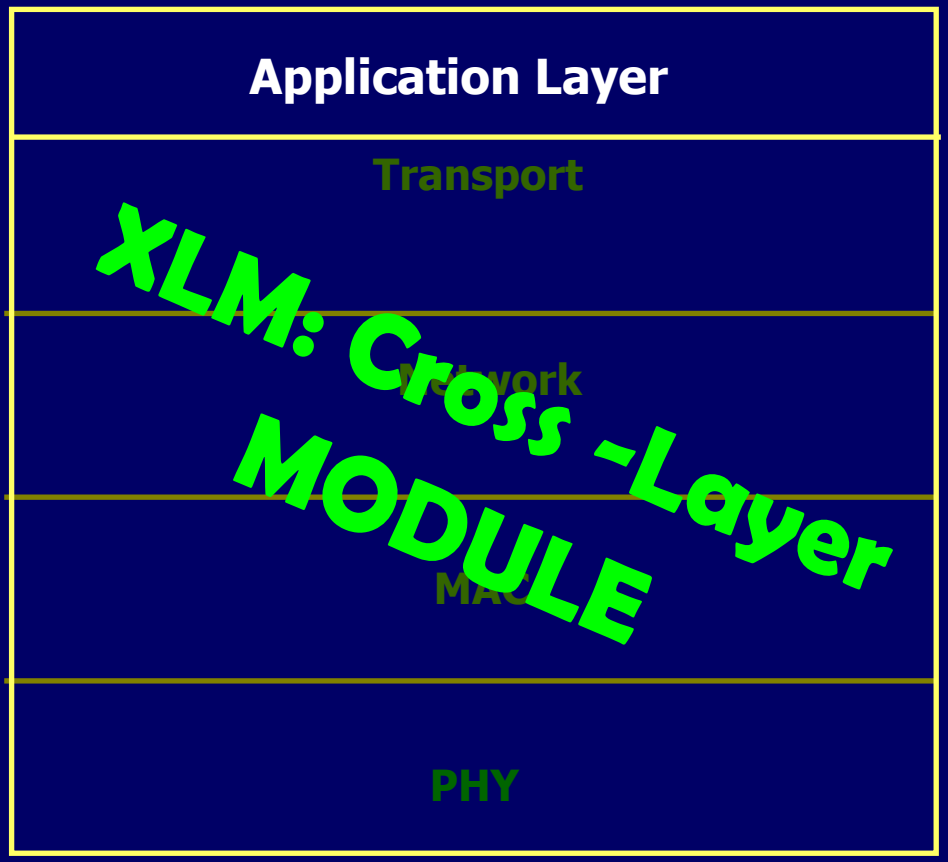
Cross-Layer Melting



Our View

XLM: Cross-Layer Module

M. C. Vuran, O. B. Akan, and I. F. Akyildiz,
"XLM: A Cross Layer Module for Efficient Communication in Wireless Sensor Networks," January 2006



GRAND CHALLENGE 2:

HOW TO REALIZE THE MAPPING??

User Requirements/ Applications

Architecture and Topology

Communication Protocols

FURTHER GRAND CHALLENGES

- Cost Reduction to CENTS ??
- Deployment (Architecture) Decisions
  (optimal # of sensors, optimal # of sinks, optimal locations, fast deployment, reusability, terrain considerations)
- How to deal with TERABYTE of sensed information?
- How to integrate WSNs into NGWI ??
- Optimal Packet Size and Error Control
- Scalability
- SECURITY

FURTHER PHYSICAL LAYER CHALLENGES

- New Channel Models (I/O/Underwater/Underground/Deep Space)
- Explore Antenna Techniques
- Cognitive Radios ??
- UWB ??

CURRENT PROJECT@GaTech: DoD and NSF Grand Challenges in WSNs

Wireless Sensor and Actor Networks

I.F. Akyildiz and I. H. Kasimoglu,
"Wireless Sensor and Actor Networks: Research Challenges" Ad Hoc Networks Journal (Elsevier), pp.351-367, Oct. 200

GRAND CHALLENGES:

- Sensor-Actor Coordination & Communication
- Actor-Actor Coordination & Communication

REAL-TIME COMMUNICATION!!!!

SENSOR-ACTOR COORDINATION

Challenges:

- Which sensor(s) communicate with which actor(s)?
- How should the communication occur?
- What are the requirements of the communication?
  (i.e., real-time, energy efficiency)

ACTOR-ACTOR COORDINATION

Challenges:

- Which actor(s) should execute which action(s)?
- What is the optimum number of actors performing the actions?

CURRENT PROJECT@GaTech: **NSF & DoD**

Exploring Spatial and Temporal Correlation for WSANs

GRAND CHALLENGE:
Multimedia Sensor Networks

I.F. Akyildiz, et. al. "Wireless Multimedia Sensor Networks: Research Challenges", May 2006

- **Differentiation between traffic types**

  Integrated Traffic: (AUDIO, VIDEO, DATA, STILL IMAGE)

  - Delay in/sensitive, Jitter in/sensitive, Loss in/sensitive, Different data rates

- **Channel Allocation and Scheduling (Multimedia Traffic Management)**

FURTHER GRAND CHALLENGES in Multimedia Sensor Networks

- How to guarantee delay bounds; jitter bounds?
- How to realize data aggregation?
- Explore the tradeoffs between media quality and energy consumption!!
- Differentiation of TCP vs UDP traffic
- Distributed source coding at different sensors
- Synchronization (intra-media, inter-media)
- Cross-layer design for multimedia traffic

Underground Wireless Sensor Networks

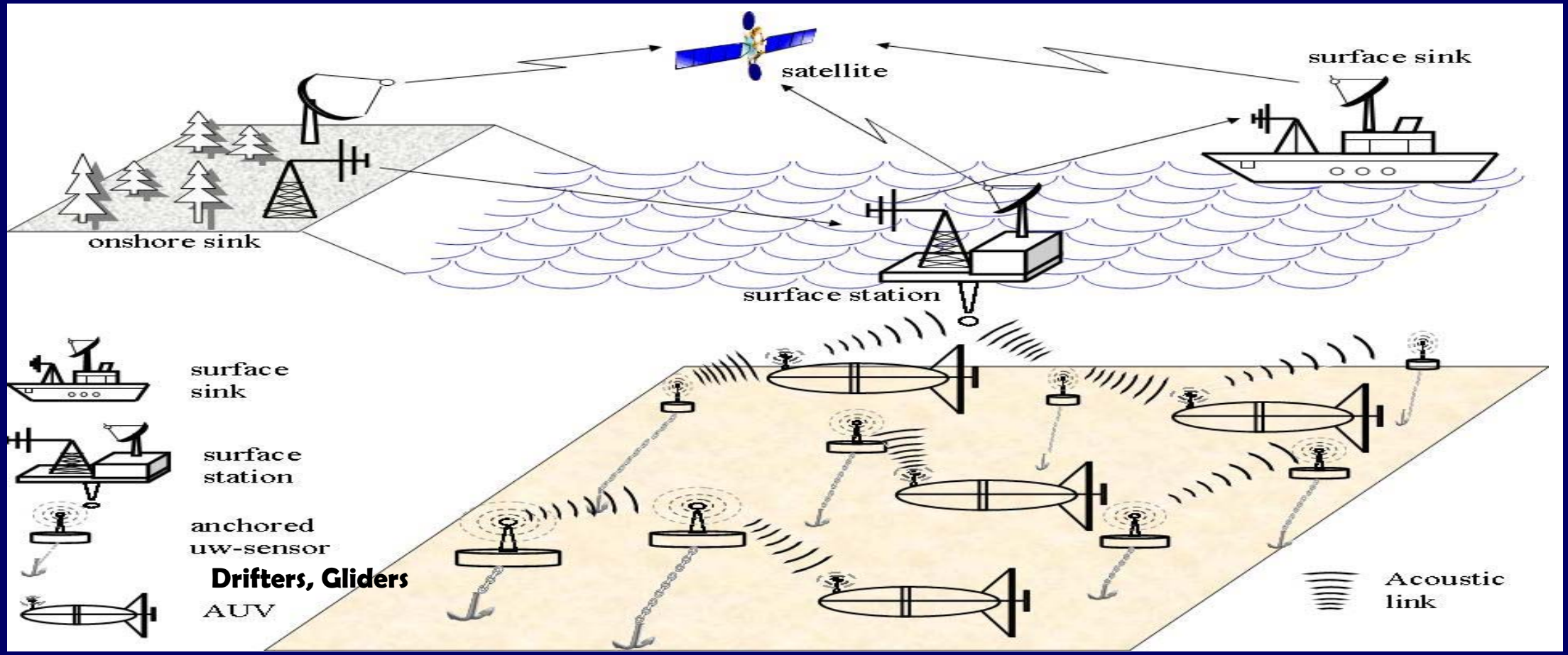
I.F. Akyildiz and Erich Stuntebeck, "Underground Sensor Networks: Research Challenges", March 2006.

Underground WSNs: Research Challenges

- Dynamic Channel
- Power Constraints
- Very Low Data Rates
- Extremely Lossy Environment
- New Communication Protocols needed

UNDERWATER SENSOR NETWORKS

I.F. Akyildiz, D. Pompili, T. Melodia, "Underwater Acoustic Sensor Networks: Research Challenges", Ad Hoc Networks (Elsevier) Journal, March 2005



LATEST DARPA MISSION:

BAA-06-13: SUSTAINABLE LITTORAL SURVEILLANCE (Energy Sources, Sensors, Platforms)

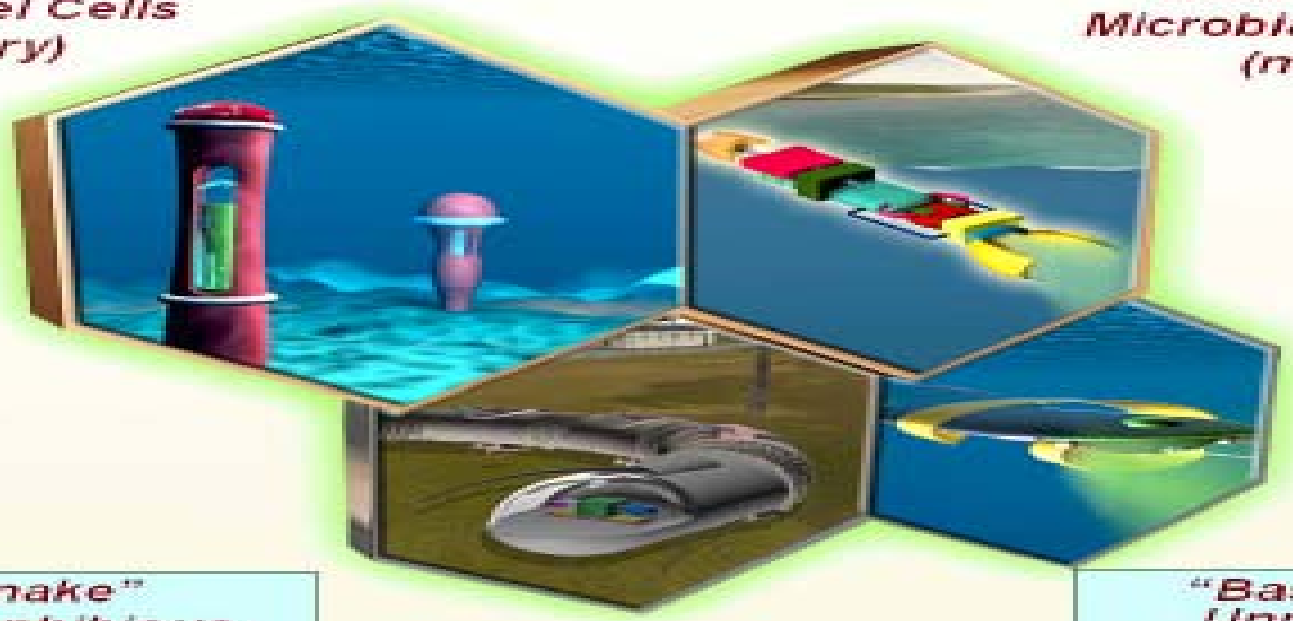
TODAY: Littoral World with Highly Capable, High Priced Assets
but without "Sustained Presence"

SUSTAINABLE LITTORAL SURVEILLANC

Four Part Development Approach
(to achieve true *Sustained* Littoral Surveillance)

Bottom Mounted Microbial Fuel Cells (stationary)

Water Column Microbial Fuel Cells (mobile)



"Remora-Snake" Unmanned Amphibious Surveillance Platform

"Basking Shark" Unmanned Gliding Surveillance Platform

Research Challenges for UW Sensor Network

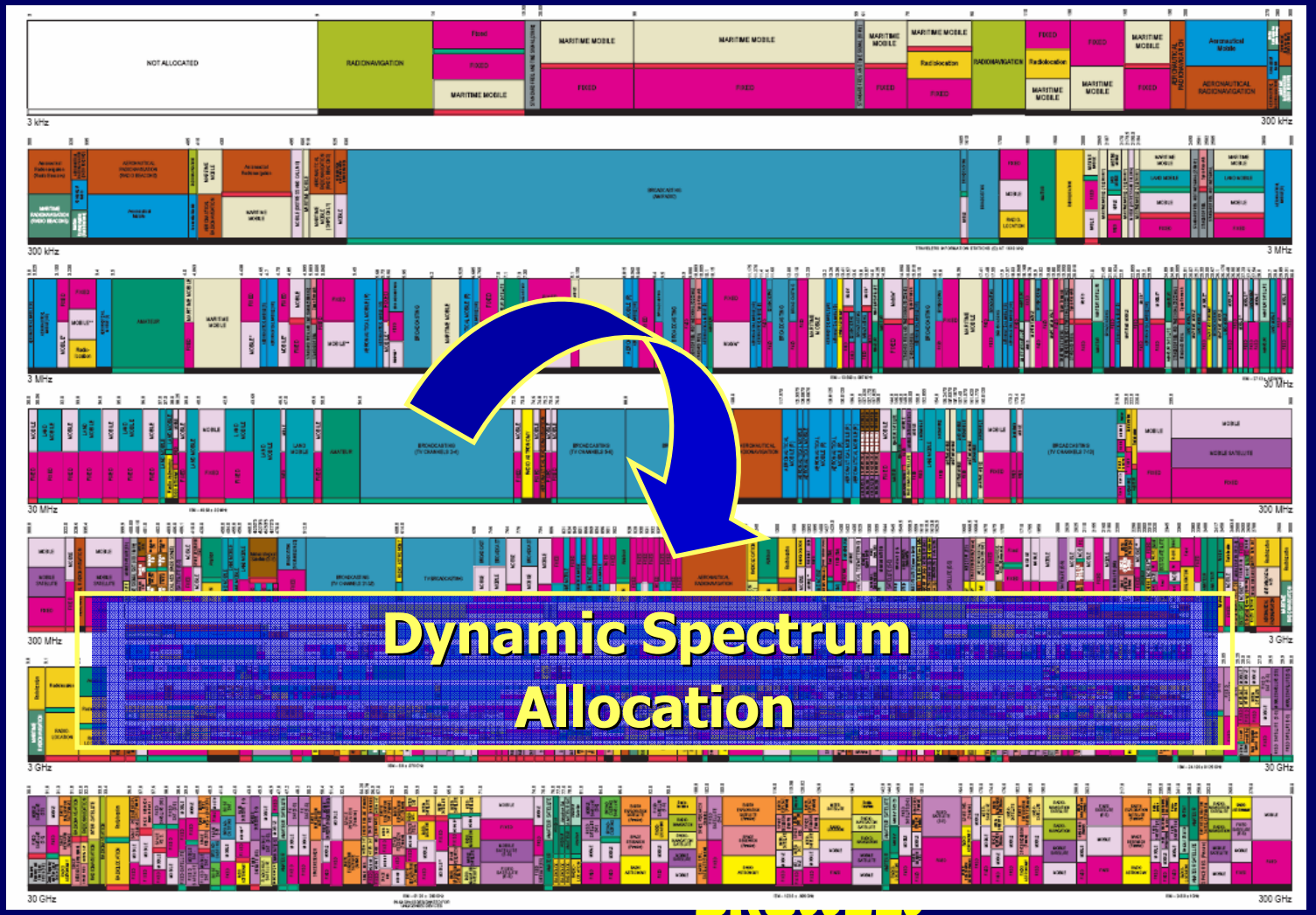
- Available bandwidth is severely limited
- UW channel is severely impaired (in particular due to multi-path and fading)
- Very long and extremely variable propagation delays
- Very high bit error rates and temporary losses of connectivity (SHADOW ZONES)

Research Challenges for UW Sensor Network

- Battery power is limited and usually batteries cannot be recharged; no solar energy!!
- Very prone to failures because of fouling, corrosion, etc.
- New communication protocols needed!!

Current Project@GaTech: US NAVY
Fundamentals and Protocols for Efficient Communication in UWSNs

DYNAMIC SPECTRUM ALLOCATION NETWORKS (xG WIRELESS SYSTEMS; COGNITIVE RADIO NETWORKS)



RESEARCH CHALLENGES in DSANs

I.F. Akyildiz et.al., "Dynamic Spectrum Access (DSANs/xG/Cognitive Radio) Networks: Research Challenges", Computer Networks (Elsevier) Journal June 2006.

- Architecture
- Cognitive Radio Design
- Mobility Management
- Spectrum Management
  - * Spectrum Sensing
  - * Spectrum Decision
  - * Spectrum Handoff

RESEARCH CHALLENGES in DSANs

- Spectrum Sharing
- Sensing Algorithms
- Interference Problems
- Higher Level Protocols Adaptivity
- Fairness and Security

Current Project@GaTech: NSF and DoD

OCRA: OFDM Based Cognitive Radio Networks