# EECS 369 – Introduction to Sensor Networks

Winter 2011

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# Staff,
# Course Overview:

## - Positioning of the WSN

# Teaching staff

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- Instructors:
  - Peter Scheuermann
    - peters@eecs.northwestern.edu
    - Office hours: TBA
  - Goce Trajcevski
    - goce@eecs.northwestern.edu
    - Office hours: M/W 2:00-3:00PM (or by appointment), L360
- Class location/time
  - Lecture: MW 3:30-4:50, Tech M152

# Textbooks

- Required:
  - F. Zhao and L. Guibas, "*Wireless Sensor Networks: An Information Processing Approach*", Morgan Kaufman, 2004
- Recommended:
  - W. Stallings, *Wireless Communications and Networks*, 2nd Edition, Prentice Hall, 2005.
  - I. Stojmenovic (editor) *Handbook of Sensor Networks: Algorithms and Architectures*, John Wiley and Sons, 2005.
  - \+ Many Reading Assignments (References from Conference Proceedings and Journals)

# Homeworks, Labs, and Exams

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- "~3" projects, 1 exams, 1 presentation, participation…

- Grading:
  - Project #1 (12%)
  - Project #2 (15%)
  - Project #3 (15%)
    - Project #3.5 (possibly)
  - Midterm (30%)
  - Presentation (20%)
- Late Policy
  - After 1 day, maximum score is 90%
  - After 2 days, maximum score is 80%,

# Policies:

- Programming Assignments are due at 11:59PM on the specified date (unless otherwise announced)
- Announcements:
  - Individual responsibility to keep up-to-date:
    - In-class, Email; Blackboard;
- Incomplete Grades
- Cheating

# Lectures:

- Introducing Abstractions:
    - Issues in WSN context per se'
    - Applications
        - Motivation
- Resources:
    - TelosB motes (TinyOS 2.x)
    - Freely available: www.tinyos.org
- NOTE:
    - It is students personal responsibility to ensure that the submitted assignments will run in the environments specified in the handouts

# Tentative Outline

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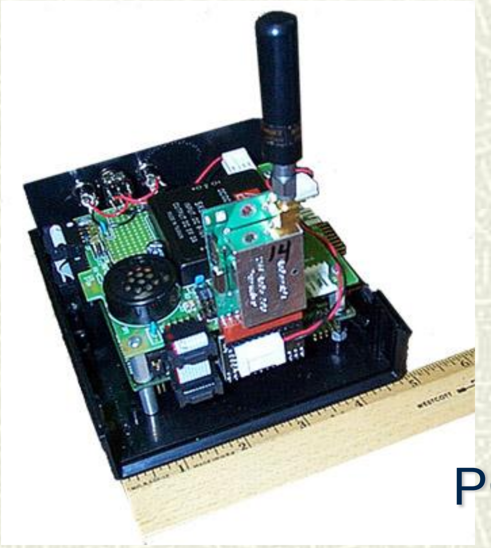
| | |
|---|---|
| 1.Introduction/Applications | • Application domains of sensor networks.<br>• Enabling technologies: hardware/software platforms.<br>• Performance metrics. |
| 2. Communication Model | • Wireless sensor architecture and protocol stack.<br>• Basics of RF communication and the role of MAC.<br>• Popular protocols (802.11, 802.15, Bluetooth). |
| 3. Localization and Coverage | • Global location (GPS-based) and relative location (Beacon-based).<br>• Localization methods: anchor-free, anchor-based, range-free, range-based.<br>• Timing/synchronization<br>• Coverage and connectivity: properties and quality aspects. |
| 4. Routing | • Data centric-protocols: gossiping, rumor routing, directed diffusion.<br>• Hierarchical protocols: LEACH.<br>• Location-based (Geographical) protocols and energy-aware routing: GPSR, geometric spanners, distributed topology routing (PRADA).<br>• Multipath-routing |
| 5. Query Processing in Sensor Networks | • Fundamentals of query approaches: push vs. pull based processing.<br>• Review of SQL.<br>• In-network processing and aggregation: TinyDB and TAG.<br>• Statistical approaches to computing aggregates: quantile-digest.<br>• Robust aggregation: ODI synopses. |
| 6. Mobility and Tracking | • Tracking with Binary Sensors<br>Distributed trajectory tracking and data reduction<br>Selection of tracking principals. |
| 7. RFID Systems | Tag identification protocols<br>Reader anti-collision algorithms<br>In-door localization with RFIDs |
| 8. Advanced Topics | • Security in WSN.<br>• Real-time query scheduling<br>• Integrating event-streams with signal processing operations |

# Sensor Networks: The Vision

- The "many - tiny" principle: wireless networks of thousands of inexpensive miniature devices capable of computation, communication and sensing
- For smart spaces, environmental monitoring, battlefield applications...

Berkeley Mote

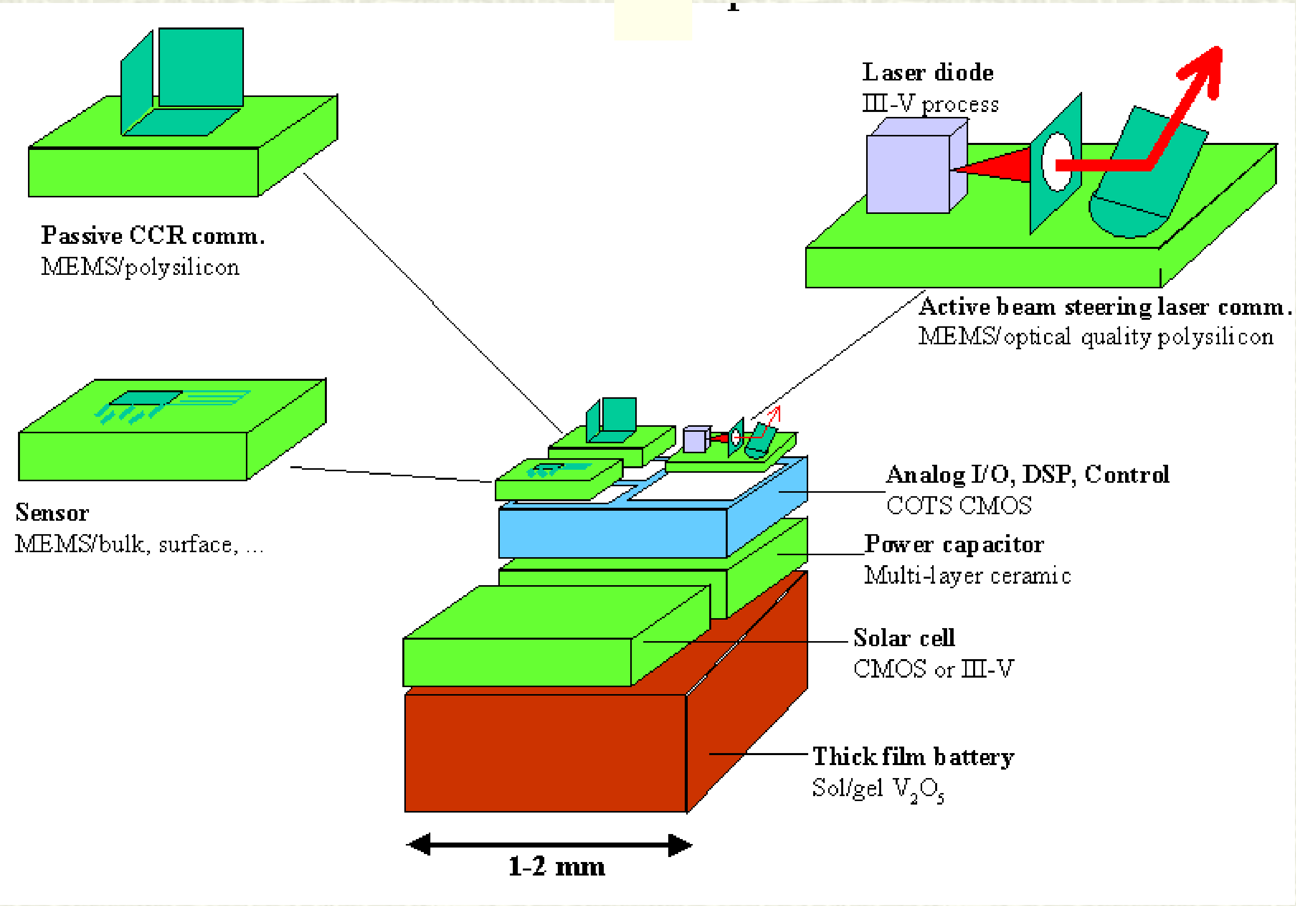


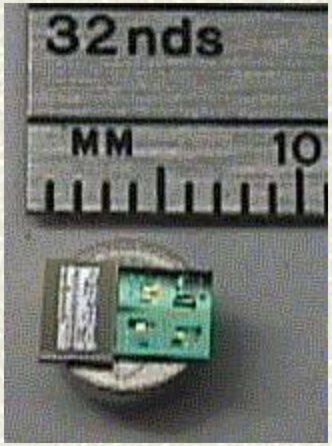
PC104 Sensor

From Pister *et al.*, Berkeley Smart Dust Project

# Tomorrow's Devices



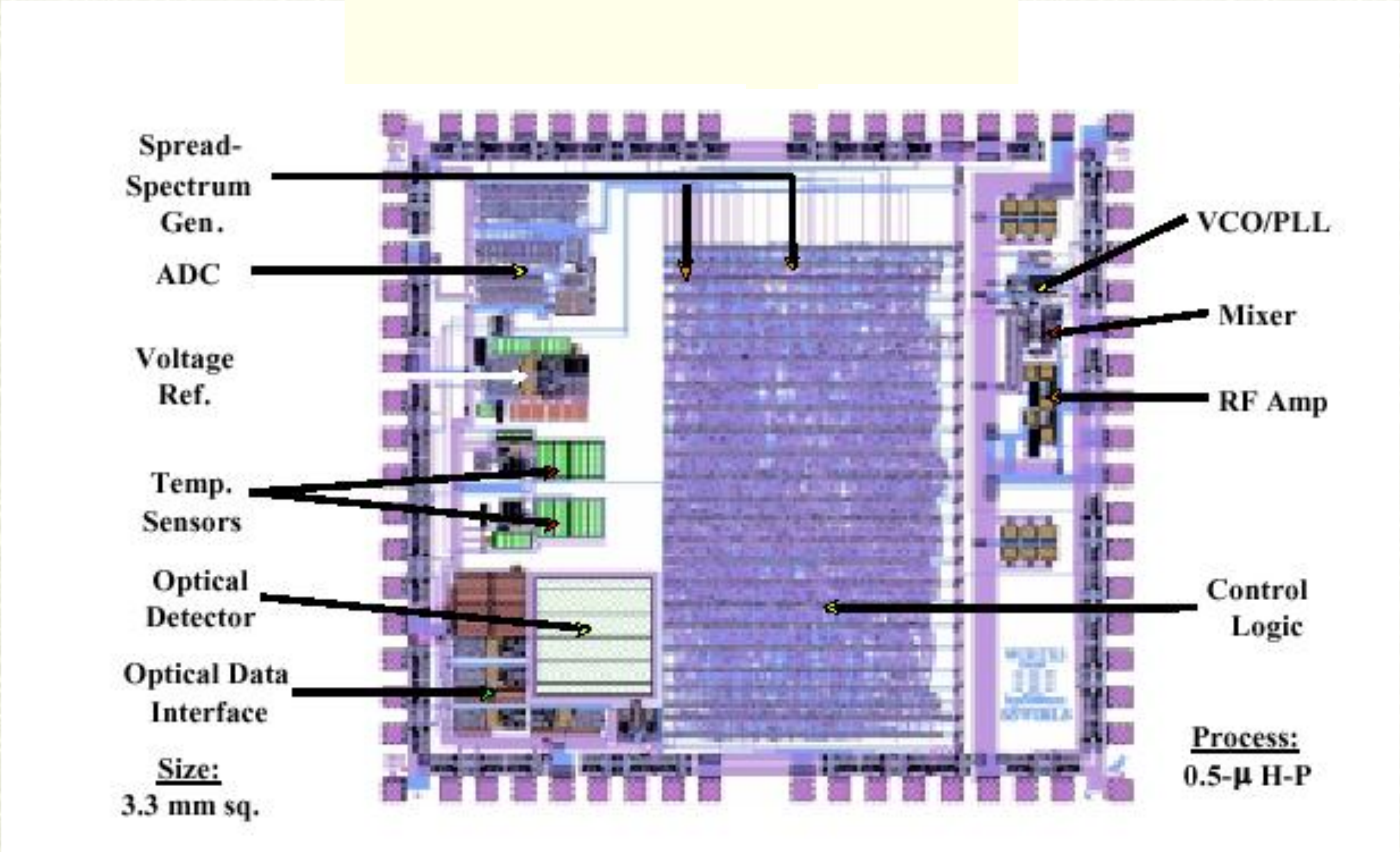



Berkeley Dust Mote

From Pister *et al.*, Berkeley Smart Dust Project

# Tomorrow's Devices




ORNL Telesensor Chip

From Manges *et al.*, *Oak Ridge National Laboratory, Instrumentation and Controls Division*

# WSN Devices

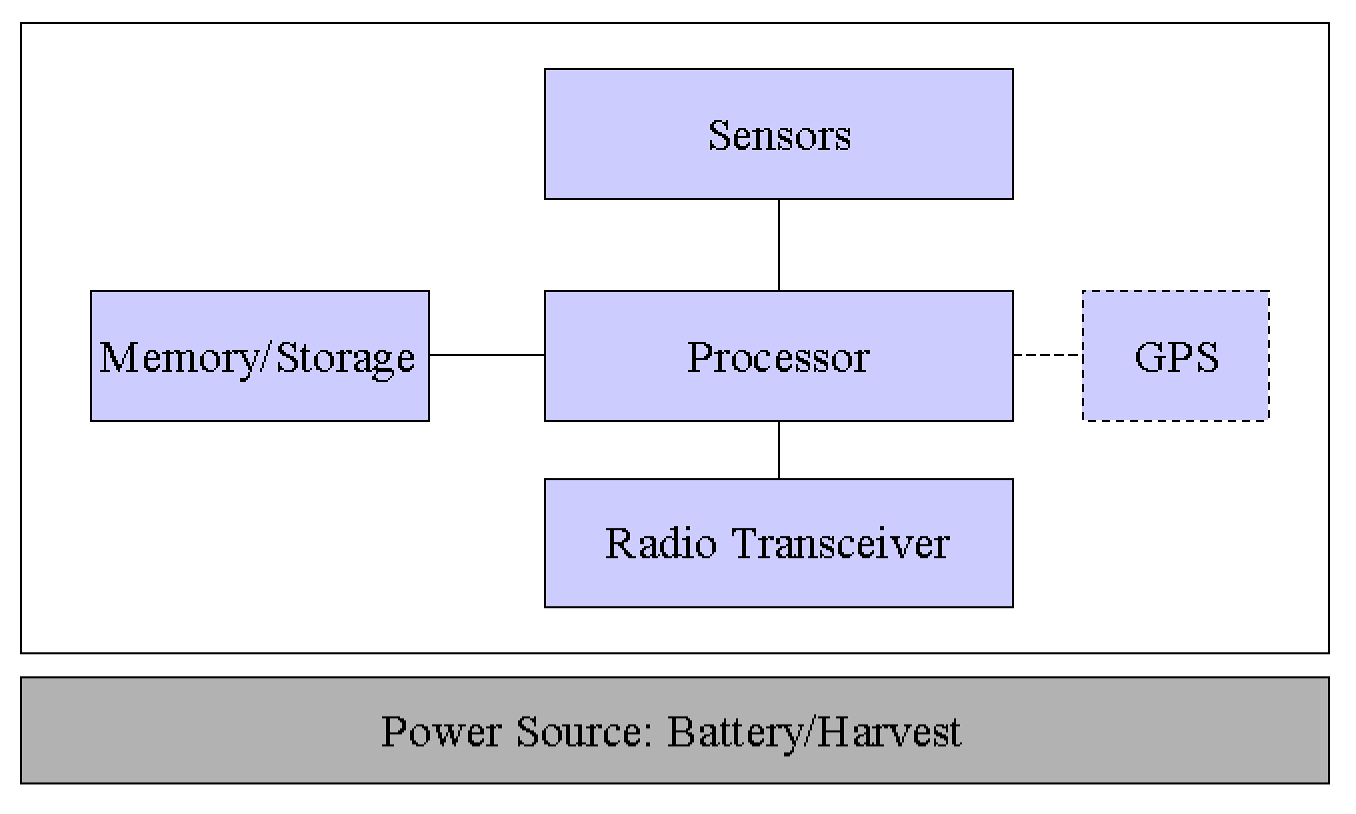
WINS (Rockwell)

MICA 2 Mote (Berkeley)

GNOMES (Rice)

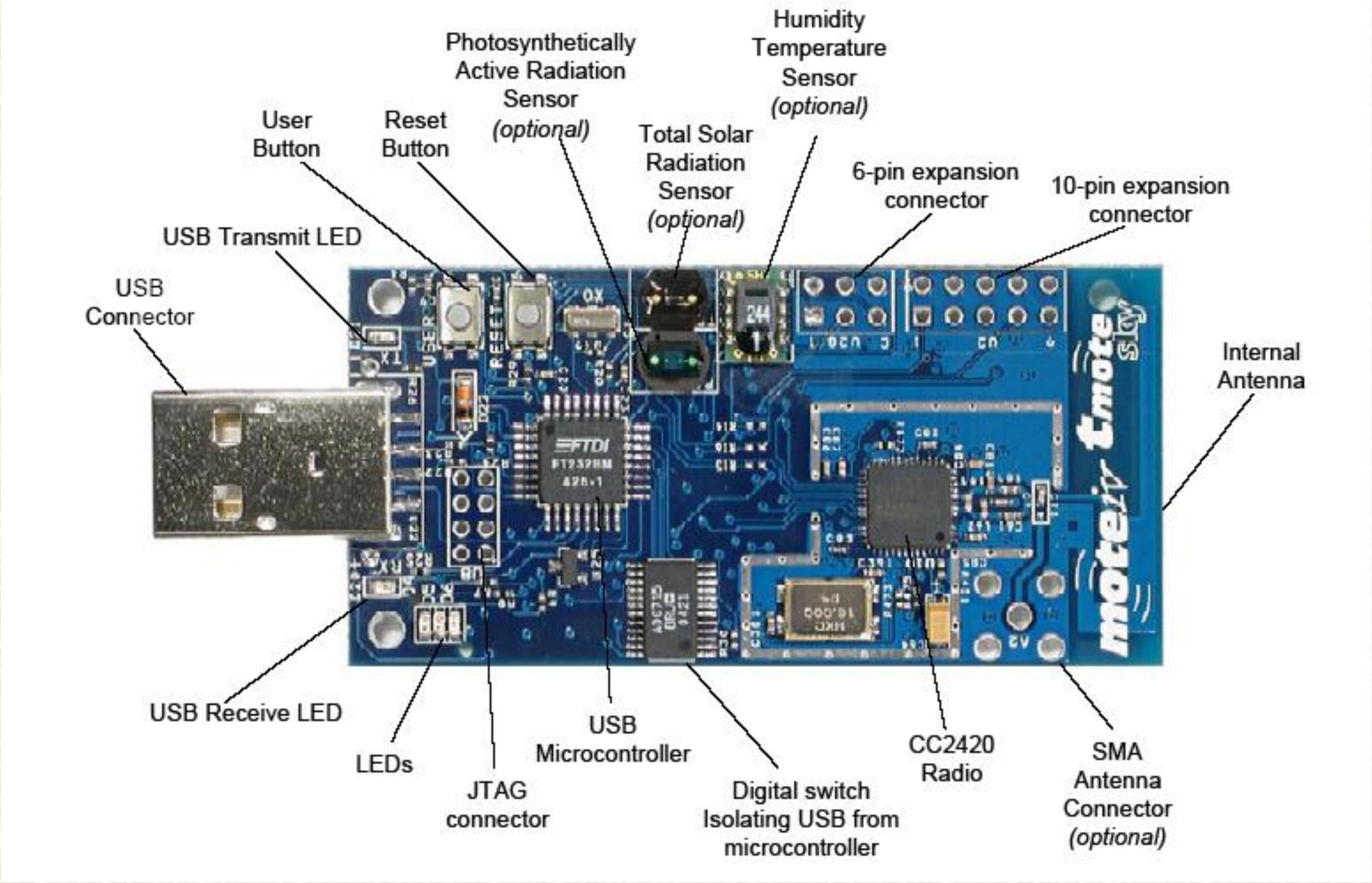
MANTIS Nymph (Colorado)

# Basic WSN Hardware



# Moteiv Tmote Sky





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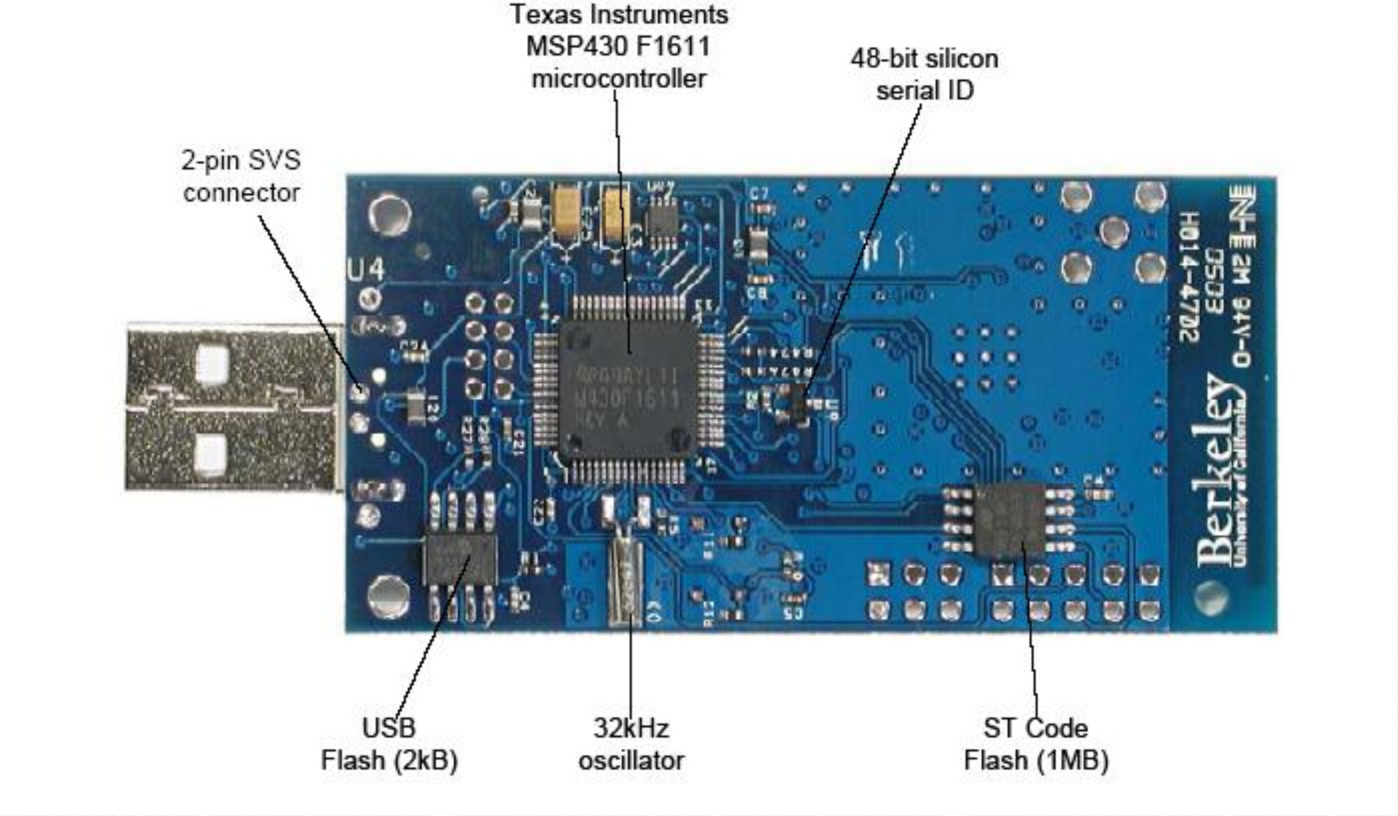

# Tmote Sky Features

- 2.4GHz, 250 kbps IEEE 802.15.4 CC2420 radio, range: tens of meters
- MSP430 microcontroller, 10k RAM, 48k flash
- 1MB external flash
- USB programming
- On-board Humidity, Temperature and Light Sensors
- Power consumption @ 3V: mcu+radio: ~20mA, mcu alone: ~2mA, standby: 20μA
- To be programmed using NesC/TinyOS 2.x

# WSN History

- 1993-4 UCLA LWIM project
- 1998 Compsys wireless sensor device
- 1999-2002: Large DARPA projects with funding for multiple university and industry teams: SensIT, PAC/C
  - WINS (successor to LWIM at UCLA)
  - uAMPS (MIT)
  - Smart Dust / Motes / TinyOS (UCB, Berkeley Intel Lab)
  - PicoRadio (UCB)
  - SCADDS (USC), PASTA (USC)
  - Cornell, U. Wisconsin, PSU, ORNL, NIST, Rutgers
  - PARC, Ember Corp., Sensoria
- 2002 NSF Funding: CENS (at UCLA, USC is a partner)
- 2003 IEEE 802.15.4 standard for low-data rate wireless
- 2007 Ongoing effort to get IP on WSN: 6LoWPAN

# Applications of Interest



- Seismic Sensing and Actuation
- Structural Condition Monitoring

From CENS

# Applications of Interest

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• Monitoring ecosystems and species habitats

From Berkley Intel Lablet: Great Duck Island (greatduckisland.net)

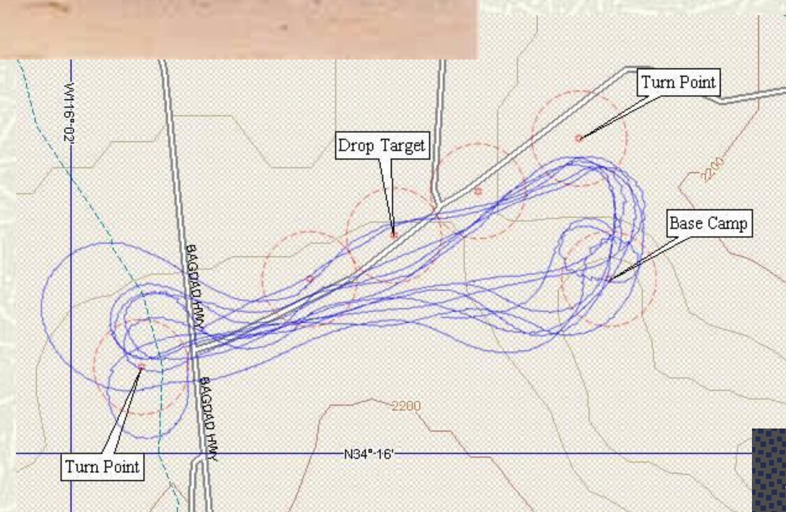
# Applications of Interest

- Contaminant Flow
- Chemical Leaks
- Forest Fires
- Emergency Response


Images from Google

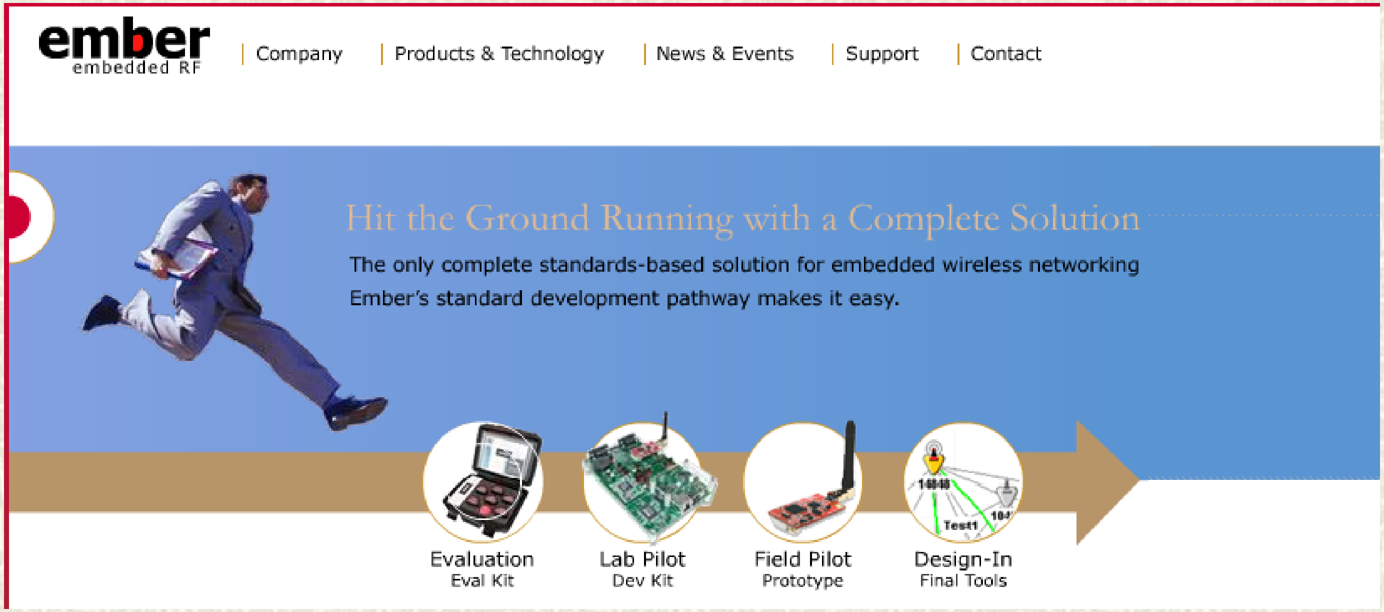
# Applications of Interest

- Target Tracking




From 29 Palms Demo, UC Berkley and others

# WSN Companies




# WSN Companies

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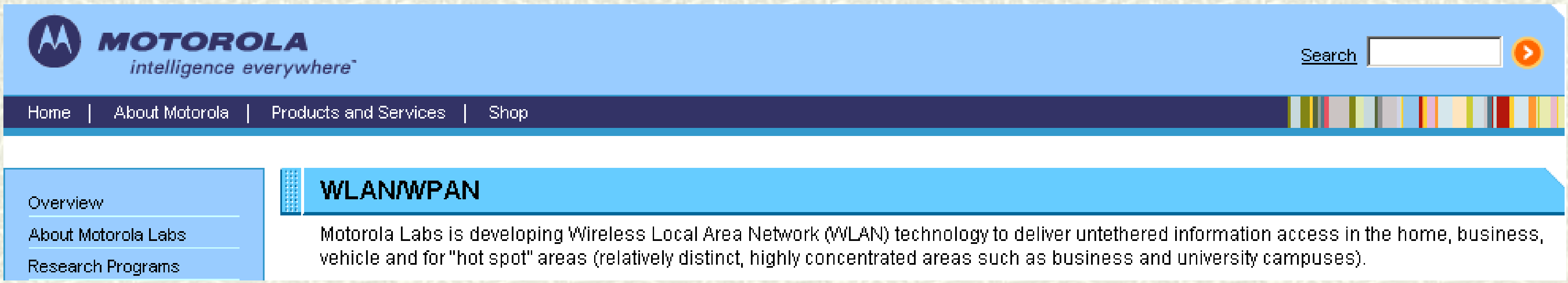


# WSN Companies


# Challenges

- Unattended, ad-hoc deployment
- Energy scarcity
  - Radio communication is 100 to 10000 times more expensive than computational processing
- Large Scale: thousands of nodes (millions?!)
- Distributed data
- Heterogeneous capabilities
- Faulty/failed nodes, noisy measurements
- Dynamic, uncertain environment
- Potentially demanding real-time constraints

# DIFFERENCES FROM AD-HOC NETWORKS

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- Number of sensor nodes can be several orders of magnitude higher
- Sensor nodes are densely deployed and are prone to failures
- The topology of a sensor network may change frequently due to node failure and node mobility
- Sensor nodes are limited in power, computational capacities, and memory
- May not have global ID like IP address
- Need tight integration with sensing tasks

# Tiered Architectures for Increased Lifetime: Mote Herds with Microserver Shepherds

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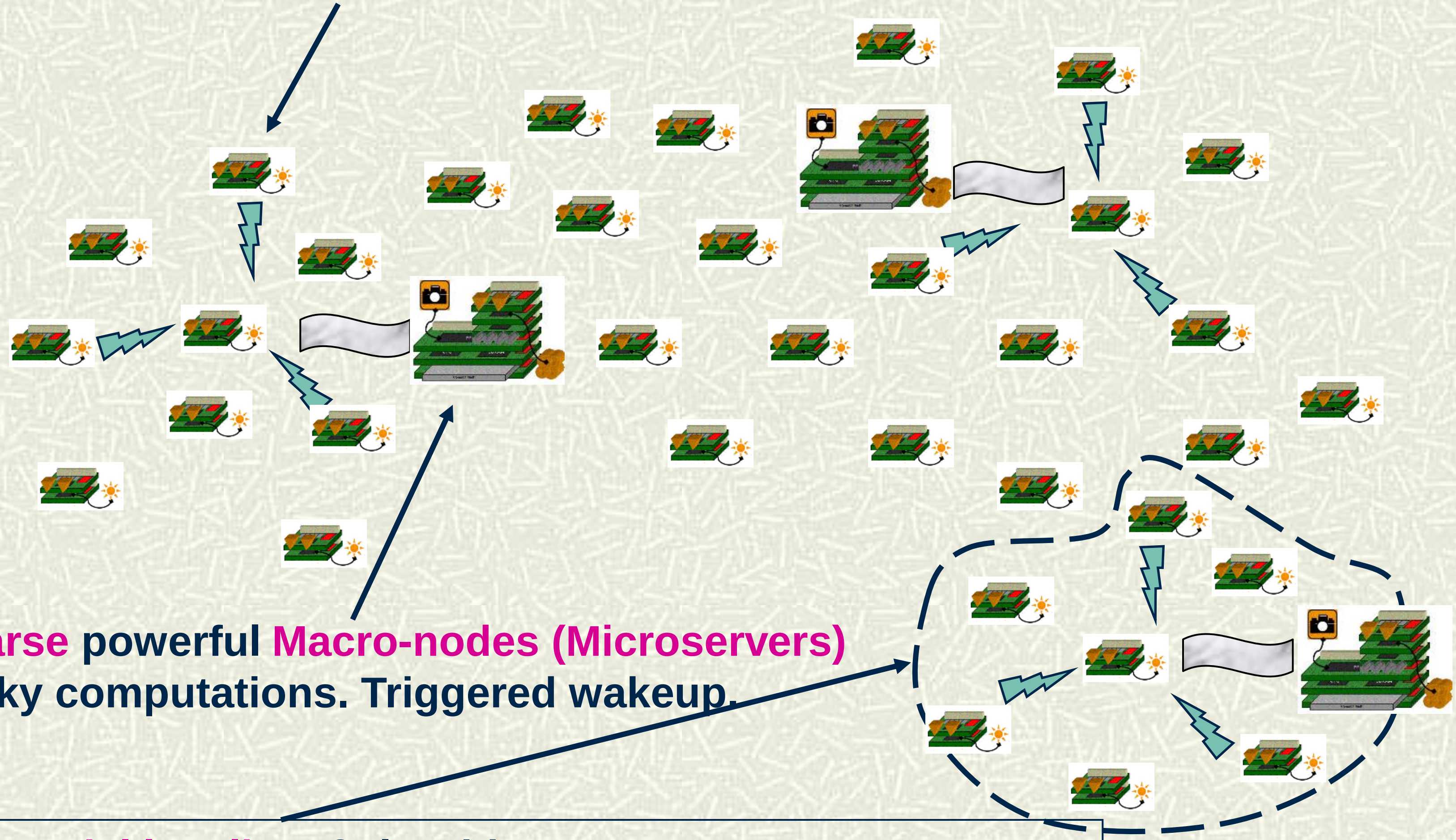
**Dense resource constrained Micro-nodes (Tripwires or Sentries)**
**Low duty cycle tasks. Mostly vigilant.**



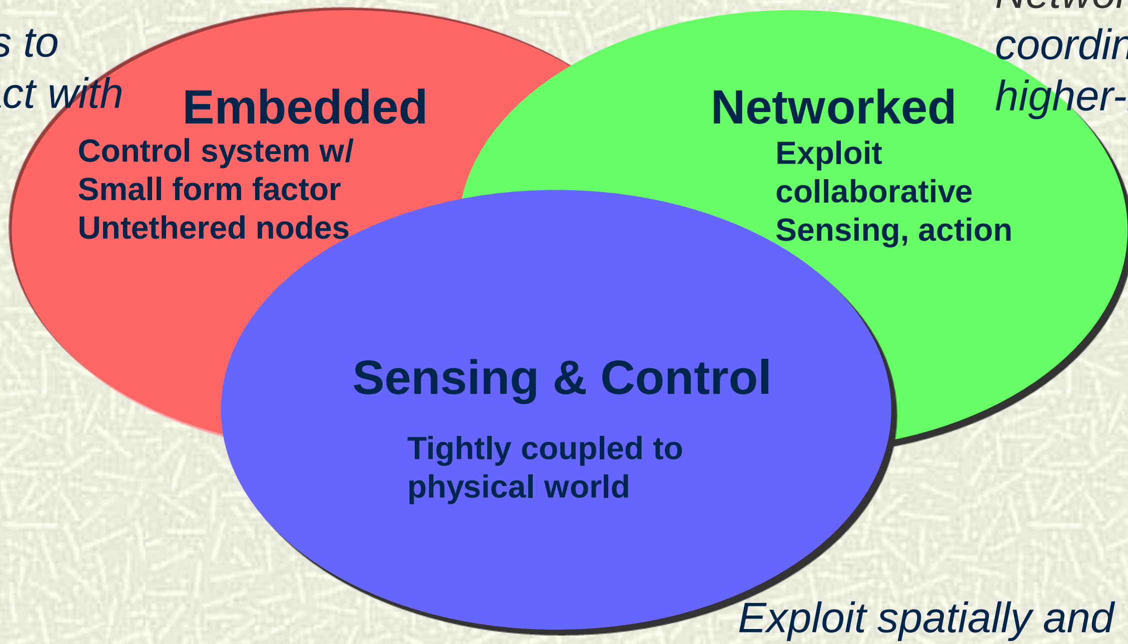
**Sparse powerful Macro-nodes (Microservers)**
**Bulky computations. Triggered wakeup.**

**Exploit spatial locality of algorithms**
**Fine grained coverage, higher performance and lower power**

# Multidisciplinary Challenges

*Embed numerous distributed devices to monitor and interact with physical world*

*Network devices to coordinate and perform higher-level tasks*




*Exploit spatially and temporally dense, in situ, sensing and actuation*

- Large-scale
- Distributed
- Real-time (control, events)
- Physically-coupled
- Unattended
- Resource-constrained
- Wireless
- Collaborative computations

***Combines the hard problems of the Internet, Embedded Systems, Wireless Networks, and Distributed Computing!***