Complex Systems and Sensor Networking: COE Collaborative Sponsored Research

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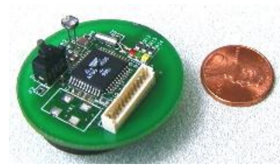
The Case for Sensor Networks

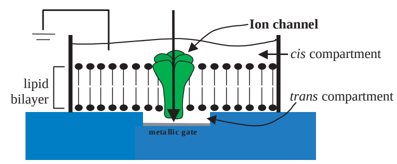
- Complex Networks in the Critical Infrastructure
  - Power Grid, Municipal Water Supplies, Telecommunications Infrastructure, National Transportation System, …
- Sensor Networks will play a critical role in monitoring and protecting CI networks.
- Sensor Networks combine several CU COE strengths.
  - Information Sciences
  - Complex Systems
  - Energy and the Environment

Numerous, Cheap, and Small

- Large numbers of small, low power sensors distributed (randomly) across coverage area
- Exploit redundancy
- Adaptive link and networking technologies
- Distributed processing, reporting tools



Berkeley Dust Mote



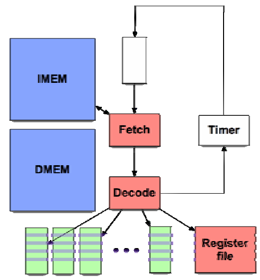
Wadsworth/Cornell Biosensor

CU Sensor Networking Effort Emphasizes Core Strengths

- Asynchronous (event-driven) ultra-low power processing technologies (ECE)
- Ad hoc link and networking technologies (ECE)
- Game-theoretic approaches to self-configuration (ECE/Econ)
- Specialized Operating System Design (CS)
- Software Reporting Tools (CS)
- Information Security (CS, IAI)
- Infrastructure Modeling (Civil)
- Impact of Human/System Interaction (AEM)

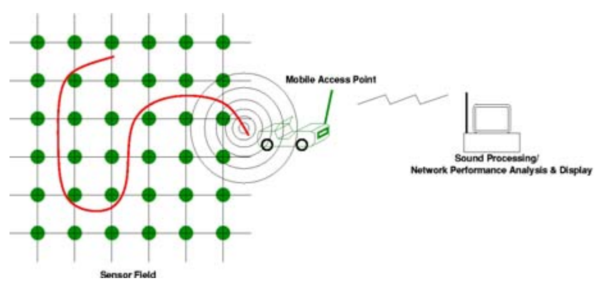
Platform Technologies: SNAP Asynchronous Processor (Manohar, ECE)

- Clockless logic
  - Spurious signal transitions (wasted power) eliminated
  - Hardware only active if it is used for the computation
- MIPS: high-performance
  - 24pJ/ins and 28 MIPS @ 0.6V



Processor	Bus	Year	E/op	Ops/sec
Atmel	8	200?	1-4 nJ	4 MIPS
StrongARM	32	200?	1.9 nJ	130 MIPS
MiniMIPS	32	1998	2.3 nJ*	22 MIPS
Amulet3i	32	2000	1.6 nJ*	80 MIPS
80C51 (P)	8	1998	1 nJ**	4 MIPS
Lutonium	8	2003	43 pJ	4 MIPS
SNAP	16	2003	24 pJ	28 MIPS

Link and Networking Technologies



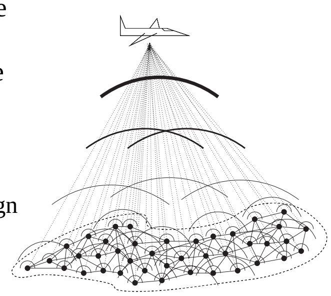
- Exploit characteristics specific to sensor nets.
- Novel MAC protocols
  - Incorporation of mobile access points
  - “Opportunistic” multiple access
- Self-Configuring Networks
  - Emergent routing protocols
  - Distributed power and coverage control

Operating Systems

- MagnetOS (Sirer, CS)
  - Provide a unifying single-system image abstraction
  - Converts applications into distributed components that communicate over a network
  - Transparent component migration
  - Power-efficient
- Tiny OS
  - Large, active open source community:
  - 500 research groups worldwide
  - OEP for DARPA Network Embedded Systems Technology
  - Thousands of active implementations - impact of security innovations will be extremely high

Research Teams: 2003 NSF ITR

- "Self-Configuring Sensor Networks for Disaster Mitigation and Recovery"
- Goal: Self-configuring, rapidly-deployed networks of bio-sensors for use by rescue personnel.
- Team includes electrical engineers, game theorists, molecular biologists, and civil engineers.
- Multi-layer approach
  - sensor development tied to network design
  - network design tied to specific applications involving urban critical infrastructure
- Work conducted in collaboration with Wadsworth Laboratory, New York Department of Health.



Research Teams: 2004 NSF Nets_NOSS

- "Ultra Low-power, Self-Configuring, Wireless Sensor Networks"
- Goal: Development of platform technologies for low-power sensor networks.
- Team includes electrical engineers, computer engineers, and computer scientists.
- Approach:
  - Tie operating system and low-power processor technologies to self-configuring network theme
  - Develop extensive testbed for testing and demonstrating technologies

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Pending: 2004 NSF STC

- 2004 NSF STC ($3.5 million CU) - Team for Research in Ubiquitous Secure Technologies (TRUST)
  - Berkeley (lead), Cornell, Stanford, CMU, and Vanderbilt
- Goal: System-level approach to information security.
  - Component technologies developed and incorporated through integrative testbeds to meet national security needs
  - Sensor networks are both tool and target
- Successful Site Visit - 9/2004
- Blue-Ribbon Panel - 12/2004
  - 6 to be chosen from 12

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Sponsored Research in Sensor Networking

- 2003 NSF ITR ($2.5 million) - Self-Configuring Sensor Networks for Disaster Prevention, Mitigation, and Recovery
- 2004 NSF Nets_NOSS ($1.5 Million) - Ultra Low-Power, Self-Configuring, Wireless Sensor Networks
- Pending: 2004 NSF STC ($3.5 million CU, with Berkeley, Stanford, CMU, and Vanderbilt) - Team for Research in Ubiquitous Secure Technologies (TRUST)
- Nascent: 2005 NSF ERC ($4 - 5 million CU, with Berkeley and Vanderbilt) – Sensor Networking for Critical Infrastructure Protection

COE Sensor Networking Effort

- Collaboration: 6 departments, 12+ faculty
- Graduate student support
  - Ongoing effort to increase number and quality in pool
  - Compete with peer schools by stressing group efforts
- Sensor networking testbed
  - Convincing technology demonstrations
  - East coast compliment to Berkeley effort
  - Connections to Oak Ridge through Vanderbilt

Future Development

- Funding from Dept. of Homeland Defense
  - Ongoing effort through Oak Ridge
- Incorporation of other interested faculty
  - Earth and Atmospheric Science
  - Agricultural School
  - Veterinary Schools
- Increased technology transfer
  - Mid-stack compliment to Crossbow et al.