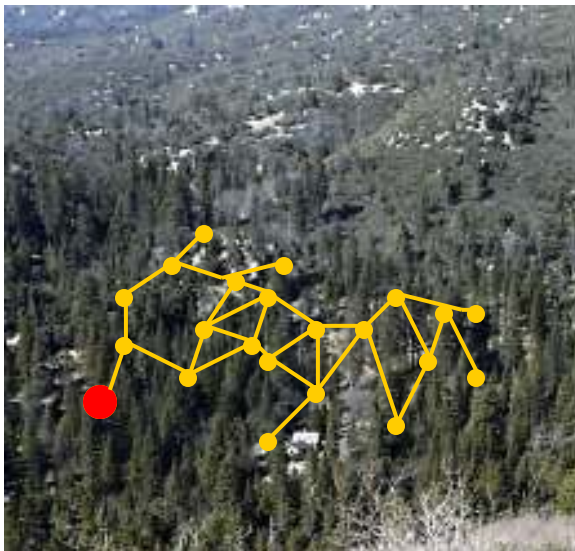


Wireless Ad Hoc and Sensor Networks

Sensor Networks: Introduction

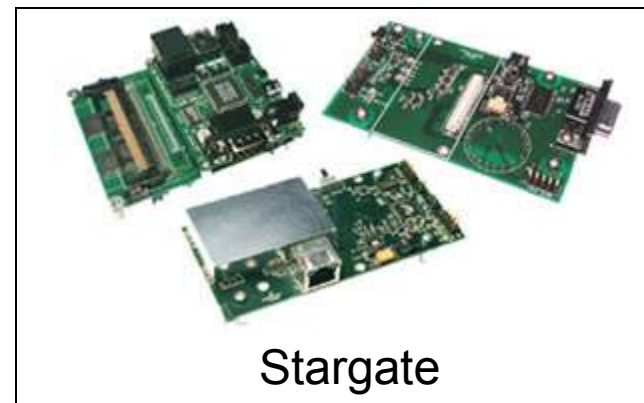
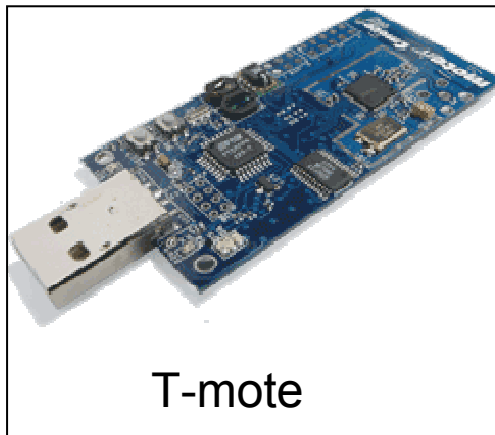
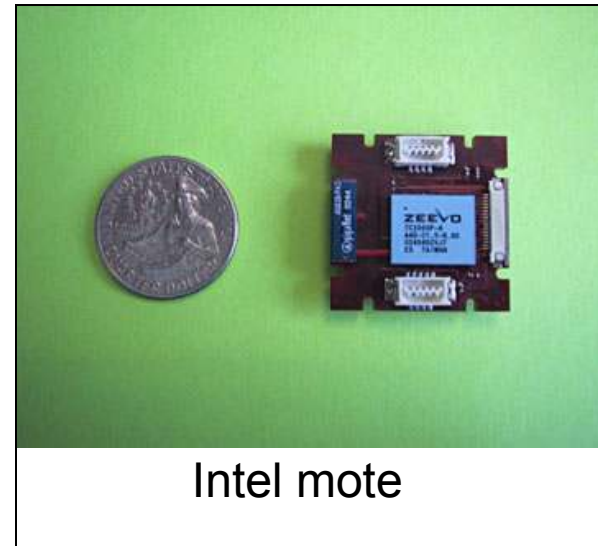


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ECSE, RPI
September 8th, 2005

What is a sensor network?

- **The vision:**
 - “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it”—Mark Weiser
- **A collection of constrained wireless-enabled sensors that interact with both the users and the physical environment, e.g.**
 - Monitor pedestrian or vehicular traffic forming intelligent transportation grids
 - Report wildlife habitat conditions for environmental conservation
 - Detect, alert and help recovering from disasters (e.g. tsunamis, floods, earthquakes, forest fires, buildings etc.)
 - Military applications (e.g. exploring urban/hostile environment)

Platforms



(See http://www.cse.unsw.edu.au/~sensor/hardware/hardware_survey.html for a decent summary)

*	<u>WINS NG 2.0 Node</u>	<u>Berkeley MICA Mote</u>	Smart Dust
Cost	\$100s	\$10s	<\$1
Size (cm ³)	5300	40	.002
Weight (g)	5400	70	.002
Battery Capacity(kJ)	300	15	-
Sensors	Off-board	Integrated: accel., temp., light, sound	MEMS sensor to be integrated
Memory	32 MB RAM, 32 MB flash	4 KB RAM, 128 KB flash	-
CPU	Hitachi SH4	ATmega 103L	-
Operating System	Linux	TinyOS	-
Processing capability	400 MIPS	4 MIPS	-
Radio range	100 m	30 m	-

- Newer versions may have appeared
- Data obtained from [Zhao+04]
- Our lab contains dozens of various types of motes – available for your projects

Constraints

- **Hardware Constraints**
 - Finite on-board battery power
 - Limited communication range
 - Limited processing power
 - Limited memory
- **Medium Constraints**
 - Limited Bandwidth

Why is it a new research area

- Information generated by the sensors or sent to the sensors relate to physical environments.
 - Different types of traffic (compared to Internet TCP/IP)
 - Different types of applications
- It is desirable to prolong the lifetime of the sensor network as much as possible
 - Energy consumption for communication is thousands of times more than that of computation
 - Desirable to limit communication range
- Local collaboration to save energy
 - Duplicate data suppression (or data compression)
 - Activating only relevant/necessary nodes
 - Network algorithms need to balance the coupling between
 - modes of node collaboration
 - the application requirements
 - the physical environment

Active Entities

- **Research programs in many CS departments**
 - Networking (algorithms/protocols)
 - Databases
 - Systems theory
 - Programming (e.g. middleware)
- **Research programs in EE/CE departments**
 - Networking (algorithms/protocols)
 - Low power hardware design
 - Collaborative signal processing
 - Wireless communications
 - Information theory, queuing theory, optimization
- **Industrial research activities**
 - Intel, Agilent, PARC, Sun, HP, Motorola...etc.
 - Startups Crossbow, Sensicast, Dust Inc, Ember, ...etc.
- **Funding Agencies**
 - NSF
 - Sensors and Sensor Systems program
 - Networking of Sensor Systems (NeTS)
 - DARPA
 - Control-Based Mobile Ad-Hoc Networking (CBMANET)
 - Wireless Network after Next

Canonical Problems (we think we know)

- **Data Aggregation**
 - Collecting interesting data from the sensors
- **Localization**
 - Nodes establish their position with respect to a reference point (GPS?)
- **Tracking**
 - Maintaining the location of target(s)
- **Coverage**
 - Which nodes to activate in order to map the phenomenon of interest
- **Connectivity**
 - How to adjust the transmission powers to maintain network connectivity

Advanced problems (lots of unanswered questions)

- **Collaboration**
 - Collaborative Processing
 - Collaborative Sensing
 - Collaborative Communication
- **Actuation**
 - Distributed Control?
- **Coupling of network protocols with space and time**
 - Spatio-temporal behavior of the physical phenomena of interest
 - How much coupling is reasonable?
- **Joint Optimization**
 - There is a rift between optimization and architecture

Metrics

- **Efficiency**
 - System lifetime/System resources
- **Resolution/Fidelity**
 - Detection/Identification
- **Latency**
 - Response time
- **Robustness**
 - To variable system and input state]
 - Security to malicious or buggy nodes
- **Scalability**
 - Over space and time

Conferences of Interest

- ACM Sensys, WSNA, IPSN, SNPA (ICC), Mobihoc, Mobicom, Mobisys, Sigcomm, Infocom, ICASSP, etc.

References

- [everywhere] Embedded Everywhere: A Research Agenda for Networked Systems of Embedded Computers, Computer Science and Telecommunications Board, National Research Council - Washington, D.C., <http://www.cstb.org/>
- [Zhao+04] F. Zhao and L. Guibas, “Wireless Sensor Networks: An Information Processing Approach,” Morgan Kaufman, 2004.

Planning Issues

Projects

- Teams of 3 people (6 projects)
- Suggested Topics
 1. Adaptive Power Control
 2. Position-Based Algorithms
 3. Cooperative Relaying
 4. Feedback-based ad-hoc network design
 5. Data compression & delay optimization
 6. Attacking a sensor (or ad hoc) network

-
- Project teaming: due 9/19
 - Project proposal: due 9/29
 - Project Presentations/Demonstrations:
 - 3 classes, 2 projects each class (11/21, 11/24, 11/28, 12/1)

(may also move all presentations to (long) days on 11/28 and 12/1, or one (very long) day 12/1. Will decide later.

Topics of future classes

1. Ad-Hoc Networks

- MAC protocols (2 classes)
- Routing protocols (3 classes)
- Mobility (1 class)
- Capacity (1 or 2 classes)

- Mesh Networks (1 class)
- Directional Antennas and MIMO (1 class)
- Cooperative communication (1 class)
- Power Control (1 class)

2. Sensor Networks

- Data aggregation (directed diffusion)
- Target tracking
- Sleep scheduling
- Synchronization
- Connectivity
- Localization

- In-network processing/compression
- Coverage
- Information Theoretic Approaches