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

(WINS NG 3.0)

Intel mote

T-mote

Stargate

(See [http://www.cse.unsw.edu.au/~sensar/hardware/hardware_survey.html](http://www.cse.unsw.edu.au/~sensar/hardware/hardware_survey.html) for a decent summary)
<table>
<thead>
<tr>
<th></th>
<th>WINS NG 2.0 Node</th>
<th>Berkeley MICA Mote</th>
<th>Smart Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$100s</td>
<td>$10s</td>
<td>&lt;$1</td>
</tr>
<tr>
<td>Size (cm³)</td>
<td>5300</td>
<td>40</td>
<td>.002</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>5400</td>
<td>70</td>
<td>.002</td>
</tr>
<tr>
<td>Battery Capacity (kJ)</td>
<td>300</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Sensors</td>
<td>Off-board</td>
<td>Integrated: accel., temp., light, sound</td>
<td>MEMS sensor to be integrated</td>
</tr>
<tr>
<td>Memory</td>
<td>32 MB RAM, 32 MB flash</td>
<td>4 KB RAM, 128 KB flash</td>
<td>-</td>
</tr>
<tr>
<td>CPU</td>
<td>Hitachi SH4</td>
<td>ATmega 103L</td>
<td>-</td>
</tr>
<tr>
<td>Operating System</td>
<td>Linux</td>
<td>TinyOS</td>
<td>-</td>
</tr>
<tr>
<td>Processing capability</td>
<td>400 MIPS</td>
<td>4 MIPS</td>
<td>-</td>
</tr>
<tr>
<td>Radio range</td>
<td>100 m</td>
<td>30 m</td>
<td>-</td>
</tr>
</tbody>
</table>

• 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


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