Agenda

- Wireless sensor networks
- Self Organization
- Challenges
Wireless Sensor Networks

- A network of sensor nodes to cooperatively monitor physical or environment conditions
- Sensor nodes can be deployed in hard to access remote locations
- Can survive harsh environments
Wireless Sensor Networks cont...

- **Sensor node**
  - **Power source**
    - Cells, vibrations, solar, temperature difference
  - **Processor and memory**
    - Microcontrollers, microprocessors, DSPs, FPGAs, ASICs
    - Mostly on chip memory and flash memory
  - **Sensors**
    - Current, Water flow, Liquid level, Load cell, Ultrasound, Distance Foil, Temperature, Humidity, Luminosity …
  - **Radio or Transceiver**
    - IR, RF, Optical
Wireless Sensor Networks cont...

Mica2Dot mote (25mm)

Mote sensor board

Waspmote

Event detection board for Waspmote
An application, Monitoring a large area for environmental conditions such as temperature, level of gases etc.

- Deployment
  - Random or organized
  - Dense or sparse

- Discovery and configuration
  - Discovery of neighboring nodes
  - Topology construction for the network

- Maintenance

- Routing

- Cooperative algorithms
Self Organization

- “a system is self organizing if a collection of units coordinate with each other to form a system that adapts to achieve a goal more efficiently” [T.Collier]

- “Self-organization is a process in which structure and functionality (pattern) at the global level of a system emerge solely from numerous interactions among the lower-level components of a system without any external or centralized control. The systems components interact in a local context either by means of direct communication or environmental observations without reference to the global pattern” [WSNs a survey]
Self Organization cont...

- **Self organization**
  - Sensor network consist of *small units* called sensor nodes
  - Sensor nodes have their *own state and behavior*.
  - Sensor nodes are *autonomous* and there is no central control for the system.
  - Each node has influence on the nodes in its surroundings through *local interactions* among the nodes which are coherent and coordinated.
  - *Lack of overall state* information in the sensor network. Each unit maintains its own state only
Challenges

- Hardware constraints
- Fault tolerance
- Security
- Controllability
- System testing and simulation
# Hardware overview

<table>
<thead>
<tr>
<th></th>
<th>Btnode 3</th>
<th>mica2</th>
<th>mica2dot</th>
<th>micaz</th>
<th>telos A</th>
<th>tmote sky</th>
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<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Art of Technology</td>
<td>Crossbow</td>
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<td>Atmel Atmega 128L</td>
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<td>Atmel Atmega 128L</td>
<td>Texas Instruments MSP430</td>
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<td><strong>Clock</strong></td>
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<td>7.37 MHz</td>
<td>4 MHz</td>
<td>7.37 MHz</td>
<td>8 MHz</td>
<td>7.37 MHz</td>
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<tr>
<td><strong>RAM (KB)</strong></td>
<td>64 + 180</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>10</td>
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<tr>
<td><strong>ROM (KB)</strong></td>
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<td>128</td>
<td>128</td>
<td>128</td>
<td>60</td>
<td>48</td>
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<tr>
<td><strong>Storage (KB)</strong></td>
<td>4</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>256</td>
<td>1024</td>
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<td><strong>MHz</strong></td>
<td>CC1000 315/433/868/916</td>
<td>CC1000 315/433/868/916</td>
<td>CC1000 315/433/868/916</td>
<td>CC2420 2.4 GHz 250 Kbps</td>
<td>IEEE 802.15.4 IEEE 802.15.4</td>
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<td><strong>Kbauds</strong></td>
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<td><strong>Max Range</strong></td>
<td>150–300 m</td>
<td>150–300 m</td>
<td>150–300 m</td>
<td>75–100 m</td>
<td>75–100 m</td>
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<td>Coin cell</td>
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<td>TinyOS</td>
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<td><strong>Extras</strong></td>
<td>+ Bluetooth</td>
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</table>
Challenges cont...

- **Hardware Constraints**
  - **Power or energy**
    - Energy efficient algorithms and protocols are required
  - **CPU and memory**
    - Algorithms are required which can process in available processing speed and memory
  - **Transmission range**
    - A moderate transmission range available
Challenges cont...

- **Power**
  - Affected by almost every activity
    - processing, communication, sensing …
  - Hardware optimizations
    - Low power consumption
- **Software**
  - energy efficient protocols and algorithms
Challenges cont...

- **Communication**
  - Most expensive in terms of energy consumption
  - Tx, Rx and Idle are much larger than Sleep
  - Large packets consume more energy

- **Performance**
  - Efficient implementation of algorithms for limited CPU and memory availability
  - Algorithms to use less memory accesses to save energy

Energy consumption for large (top) and small (bottom) packets in two routing protocols [EEGR]
Challenges cont...

- **Fault Tolerance and reliability**
  - Various sources of faults
    - Environmental changes, malicious activity, hardware failures, software bugs
  - Fault detection, identification, prevention, isolation, recovery
  - Requirements vary with applications
  - Failure of nodes may be critical
    - Some nodes may be the connection points for others
  - Various points of failure
    - Topology changes, communication, low energy, persistency,
Security and privacy
- Data confidentiality, integrity, authentication, message freshness
- Energy efficiency
  - Encryption and authentication causes overhead (14% and 3% in one study)
- Key distribution
  - Pre installed key
  - Session key establishment
- Potential attacks
  - Physical tampering, DoS, signal jamming, sinkhole, wormhole, sybil...
Challenges cont...

- **System testing and simulation**
  - Large scale testing incurs cost
  - **Several simulation tools**
    - NS2, OPNET, QualNet, Atarraya
    - **Limitations**
      - No physical layer simulation in NS2 and Atarraya
      - Limited sensor model libraries in QualNet and OPNET
      - No processing model in Atarraya
Examples

- **Data aggregation**
  - To reduce number of messages, messages size, energy efficiency

- **CDS based topology**
  - For energy efficiency by keeping nodes in sleep mode

- **Topology maintenance**
  - Uniform energy distribution among the nodes

- **Load balancing**
  - Network lifetime extension through load balancing and energy distribution among the nodes
Conclusion

- Self organization is desired in Wireless sensor networks
- Various challenges in application development in wireless sensor networks
Questions