Wireless Sensor Networks

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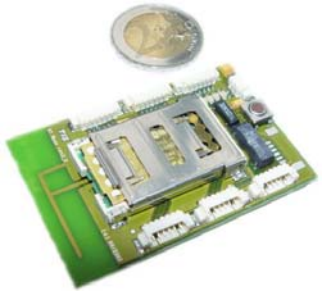
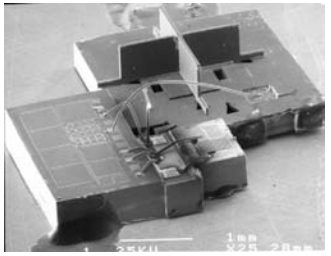
Technology

- Sensor Network
  - Large, dynamic, ad hoc network of sensor nodes
- Sensor nodes
  - Sensing, processing, wireless communication in an autonomous device
  - Small-scale, low-cost



Smart-It

Berkeley Mote



Smart Dust

Application Areas

- Killer app: Monitoring something or somebody
- Habitat monitoring
  - Behaviour and activities of animals
- Environmental monitoring
  - Seismic activities, environmental pollutions, snow quality, soil quality, fire
- Surveillance
  - Intrusion detection, traffic monitoring
- „Smart battlefield"
  - Enemy's activities

Typical Tasks

- Event detection
  - Detect/report a certain physical condition
  - Special case: target detection; detect presence/absence
- Target classification
  - Tell apart certain types of targets
- Target tracking
  - Observe target activity over time (location, speed, size, shape, track)
- Targets
  - Animals, humans, vehicles, gas, fluids, ...
  - Groups thereof

Typical Operation

- Deploy sensor nodes
  - Typically randomly
  - At any time
- Issue sensing task
  - „User“ issues high-level task via „gateway“
  - Split high-level task into simpler sub-tasks
  - Distribute sub-tasks among nodes
- Report results
  - Nodes sample sensors -> time series
  - Preprocessing -> extract „interesting“ events
  - Fusion of events -> high-level result

Characteristics

- Nodes are small, cheap, unreliable
  - Node ressources (energy, computing power, memory, comm. range and bandwidth) very limited
  - Network must tolerate node failures
- Dynamic ad hoc networks
  - Depleted batteries, destruction, re-deployment, temporary obstructions, mobility
- Large scale
  - Large numbers of nodes, high node density
- Unattended operation
  - In remote, toxic, or inaccessible regions

Requirements I

- Energy efficiency, longevity
  - Minimize per-node energy consumption
  - Equalize network energy comsumption
- Self-organization
  - Automatic configuration, error recovery
- Scalability
  - Networks of thousands-millions of nodes
- Robustness
  - Tolerate node failures

Requirements II

- Safety
  - Guarantees in life-critical systems
- Realtime Issues
  - Guaranteed response times
- Security
  - Protect against security attacks, e.g. false information, denial of service
- Privacy
  - Protect person-centric information from misuse

Design Principles

- Localized algorithms
  - Interaction with neighborhood only
- Adaptive fidelity algorithms
  - Dynamically trade off overhead/power for output quality
- Data-centric communication and storage
  - Separate node functionality from node identity
  - Nodes are replacable
- Application knowledge in nodes
  - In-network data processing

Research Issues I

- Applications
- Hardware
  - Energy-efficient, small-scale, low-cost
  - Radios, sensors, ADC, processors, energy storage and harvesting
- Networking
  - MAC protocols
  - Routing
  - Transport protocols

Research Issues II

- Data processing
  - Sensor calibration
  - Feature extraction
  - Data fusion
  - Compression
- Operating Systems
  - Hardware abstractions
  - Virtual machines
  - Dynamic reprogramming
  - Multitasking
  - Real-time support

Research Issues III

- Infrastructure
  - Support for WSN applications
  - (Distributed) programming paradigms
    - Database view, agent view, ...
  - Services
    - Location, time, ...
  - Internet integration

Current Research

- UC Berkeley & Intel Research Labs (BWRC)
  - Motes, Smart Dust, TinyOS, TinyDB
- CENS (UCLA, USC/ISI, ...)
  - Centre for Embedded Networked Sensing
  - Hardware, Applications, Algorithms, Infrastructure
- EYES (TU Berlin, TU Delft, Alcatel, ...)
  - Energy-efficient Sensor Networks (EU)
  - Hardware, Networking, Infrastructure
- NCCR-MICS (ETHZ, EPFL, ...)
  - Mobile Information and Communication Systems
  - Includes WSN topics