Part I: Introduction to Wireless Sensor Networks

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Sensors
Work in Progress: Test-bed at DTU
Wireless Sensor Networks

Sink

Sensor

Sensed Area
Outline

• Wireless Sensor Networks
  – Types and Topologies
  – Applications
  – System Challenges
• Energy Harvesting
Types of Nodes

Sensor
- Low resources
- Inexpensive
- Energy constraints
  - Main challenge!!

Sink
- High resources
- AC power supply
- Internet connection
  (typically)

Typically traffic is generated by the sensors and it is directed to the sink
**Unstructured vs. Structured**

**Unstructured**
- Dense
- Ad hoc

**Structured**
- Fewer sensors
- Strategic positions

Forest

Railway
Topologies

Multi-sink
- Increased cost
- Increased performance
- Reliability

Mobile sinks
- Move and gather data
Topologies: Single- vs. Multi-Hop

Single-Hop
- Short coverage
- Less challenging
- Higher deployment costs per m²

Multi-Hop
- Large Coverage
- Challenging
Topologies: Wireless Mesh Network

Very large sensed areas
– Wireless links of several hundreds of meters

- Sink w/o Internet Connection
- Central Station w/ Internet Connection
Outline

• Wireless Sensor Networks
  – Types and Topologies
  – **Applications**
  – System Challenges

• Energy Harvesting
Application Types

• Monitoring
  – Environmental, industrial and health monitoring
  – Factory and process automation
  – Logistics storage support

• Tracking
  – Tracking objects, animals, people and vehicles
  – Military, business, public transportation networks
Application Requirements

• End-to-end delay
  – Tracking, alerting applications

• Reliability
  – Long-term monitoring for off-line analysis

• Main trade-off / challenge of WSNs
  – Application requirements vs. Energy constraints
Typical applications

• Environmental monitoring
  – *Indoor environment control*: light, temperature, status of windows and doors, indoor air pollution
  – *Great Duck Island*: Sense the environment that birds live (temperature, pressure, humidity)

• Military applications
  – *A line in the Sand*: Sensors that can detect metallic objects, tracking and classifying moving objects

• Support for logistics
  – *Storage management* of barrels by BP: Detect incompatibilities in storage that may lead to explosions

• Human-centric applications
  – *Support for senior citizens*: Identify behaviors, indicate early stages of disorders, recording if they are taking medication and detect emergencies

• Other
  – *Six-sensor glove*: Movement and gesture recognition
Outline

• Wireless Sensor Networks
  – Types and Topologies
  – Applications
  – **System Challenges**
• Energy Harvesting
Challenges: Networking

Networking
- Efficient routing (i.e. path selection) in multi-hop networks
  - In terms of energy consumption / performance
- Duty cycling
  - Sleeping schedule to save energy
- Efficient MAC protocols
  - Must not waste energy in idle listening / overhearing
- Efficient Transmission Power selection
Challenges: Localization

Localization
- The problem of determining a node’s position
  - Challenging in *unstructured topologies*
- Important for applications, routing protocols (e.g. geographic routing)
- Straightforward solution: GPS
  - But, requires line of sight to satellites, consumes energy, increases cost
- Alternative estimation approaches
  - E.g. Received Signal Strength Indicator (RSSI) methods
Challenges: Synchronization

Synchronization
- The problem of assuring that different nodes have a common notion of time
- Important for applications (correlating data) and networking protocols (time scheduling, coordinated duty cycles)
Outline

• Wireless Sensor Networks
  – Types and Topologies
  – Applications
  – System Issues and Standards

• Energy Harvesting
Energy Harvesting

• Battery-powered WSNs
  – Sacrifice performance for lower energy consumption
  – Eventually will die and need battery replacement
    • Often not even possible (e.g. underground sensors)

• Energy-Harvesting WSNs
  – Extracting energy from the environment
  – Infinite lifetime but energy not always available
    • Energy sources have spatiotemporal variations
  – Batteries operate as energy buffers
Energy Sources

- Electromagnetic radiation
  - Solar power
  - Ambient indoor light
- Thermal energy
  - Room radiator
  - Machines
  - Body temperature
- Mechanical energy
  - Wind power, air currents
  - Water flows in natural channels (e.g. rivers) or in pipes
  - Vibrations
- Acoustic noise
  - High noise levels (e.g. concerts)
Design Objectives

Battery-Powered WSNs
• Maximize the lifetime while maintaining a minimum performance
• Save as much energy as possible
• Distribute the tasks and computation load as much as possible

Energy-Harvesting WSNs
• Maximize performance while maintaining energetic sustainability
• Use the surplus of harvested energy
• Use the nodes that have access to more energy to cover for nodes that they don’t to
Coming up next..

Part II: Security of Wireless Sensor Networks