Outline

● Overview
  – Environment Monitoring
  – Medical application

● Data-dissemination schemes

● Media access control schemes

● Distributed algorithms for collaborative processing

● Architecture for a Wireless Sensor Network

● Final Remarks
Overview

- A Wireless Sensor Network (WSN) consists of base stations and a number of wireless sensors (nodes).
Overview (Cont.)

Wireless Sensor Node: Components
Characteristics of Wireless Sensor Networks

- Requirements: small size, large number, tether-less, and low cost. Constrained by
  - Energy, computation, and communication
- Small size implies small battery
- Low cost & energy implies low power CPU, radio with minimum bandwidth and range
- Ad-hoc deployment implies no maintenance or battery replacement
- To increase network lifetime, no raw data is transmitted
Overview (Cont.)

Ad Hoc Wireless Networks

- Large number of self-organizing static or mobile nodes that are possibly randomly deployed
- Near(est)-neighbor communication
- Wireless connections
  - Links are fragile, possibly asymmetric
  - Connectivity depends on power levels and fading
  - Interference is high for omnidirectional antennas
- Sensor Networks and Sensor-Actuator Networks are a prominent example.
Overview (Cont.)

Distinguishing Features

WSNs are ad hoc networks (wireless nodes that self-organize into an infrastructureless network).

BUT, in contrast to other ad hoc networks:

- Sensing and data processing are essential
- WSNs have many more nodes and are more densely deployed
- Hardware must be cheap; nodes are more prone to failures
- WSNs operate under very strict energy constraints
- WSN nodes are typically static
- The communication scheme is many-to-one (data collected at a base station) rather than peer-to-peer
Overview (Cont.)

**Lifetime**
- Nodes are battery-powered
- Nobody is going to change the batteries. So, each operation brings the node closer to death.

"*Lifetime is crucial!*"

To save energy:
- Sleep as much as possible.
- Acquire data only if indispensable.
- Use data fusion and compression.
- Transmit and receive only if necessary. Receiving is just as costly as sending.
Overview (Cont.)

Scalability and Reliability
WSNs should
- self-configure and be robust to topology changes (e.g., death of a node)
- maintain connectivity: can the Base Station reach all nodes?
- ensure coverage: are we able to observe all phenomena of interest?

Maintenance
- Reprogramming is the only practical kind of maintenance.
- It is highly desirable to reprogram wirelessly.
Data Collection

- Centralized data collection puts extra burden on nodes close to the base station. Clever routing can alleviate that problem.
- Clustering: data from groups of nodes are fused before being transmitted, so that fewer transmissions are needed.
- Often getting measurements from a particular area is more important than getting data from each node.
- Security and authenticity should be guaranteed. However, the CPUs on the sensing nodes cannot handle fancy encryption schemes.
Power Supply

- AA batteries power the vast majority of existing platforms. They dominate the node size.
- Alkaline batteries offer a high energy density at a cheap price. The discharge curve is far from flat, though.
- Lithium coin cells are more compact and boast a flat discharge curve.
- Rechargeable batteries: *Who does the recharging?*
- Solar cells are an option for some applications.
- Fuel cells may be an alternative in the future.
- Energy scavenging techniques are a hot research topic (mechanical, thermodynamical, electromagnetic).
Overview (Cont.)

Radio
- Commercially-available chips
- Available bands: 433 and 916MHz, 2.4GHz ISM bands
- Typical transmit power: 0dBm.

Power control
- Sensitivity: as low as -110dBm
- Narrowband (FSK) or Spread Spectrum communication. DS-SS (e.g., ZigBee) or FH-SS (e.g., Bluetooth)
- Relatively low rates (<100 kbps) save power.
CPU

- The Microcontroller Unit (MCU) is the primary choice for in-node processing.
- Power consumption is the key metric in MCU selection.
- The MCU should be able to sleep whenever possible, like the radio.
- Memory requirements depend on the application
- ATmega128L and MSP430 are popular choices
Overview (Cont.)

Sensors

- The power efficiency of the sensors is also crucial, as well as their duty cycle.
- MEMS techniques allow miniaturization.
Applications of Wireless Sensor Networks

- Military and national security application
- Environment monitoring (examples coming)
- Medical application (example coming)
- Nearly anything you can imagine
Environment monitoring (1)

Great Duck Island

- 150 sensing nodes deployed throughout the island relay data temperature, pressure, and humidity to a central device.
- Data was made available on the Internet through a satellite link.
Environment monitoring (2)

Zebranet: a WSN to study the behavior of zebras

- Special GPS-equipped collars were attached to zebras
- Data exchanged with peer-to-peer info swaps
- Coming across a few zebras gives access to the data
Medical application

- Vital sign monitoring
- Accident recognition
- Monitoring the elderly

- Intel deployed a 130-node network to monitor the activity of residents in an elder care facility.
- Patient data is acquired with wearable sensing nodes (the “watch”)
Data-dissemination Schemes

Conventional Methods

- Direct communication with the base station
  - Sensor nodes communicate with the base station directly.
  - Energy consuming.

- Multi-hop Scheme
  - Transmit through some other intermediate nodes.
  - Energy consuming.
Clustering Hierarchy
Low Energy Adaptive Clustering Hierarchy (LEACH)

- Designed for sensor networks where an end-user wants to remotely monitor the environment. Where the data from the individual nodes must be sent to a central base station, often located far from the sensor network.
- Desirable properties for protocols on these networks:
  - Use 100’s – 1000’s of nodes
  - Maximize system lifetime
  - Maximize network coverage
  - Use uniform, battery operated nodes
- The use of distributed cluster formation and local processing to reduce global communication along with randomized rotation of the cluster-heads allows LEACH to achieve the desired properties while being energy-efficient.
Media Access Control (MAC) Scheme

Two categories of MAC schemes for wireless networks

- **Contention-based schemes**
  - Designed for minimum delay and maximum throughput.
  - Require transceivers to monitor the channel at all times.

- **Reservation-based or schedule-based schemes**
  - Detect the neighboring radios before allocating collision-free channel to a link.
  - TDMA — a natural choice for sensor networks.
MAC Scheme (Cont.)

TDMA-based solutions

- The self-organizing “super frame” algorithm
  - Super frame = TDMA period + BOOTUP period + unused bandwidth
  - Performs well only under the specific conditions.

- Power Aware Clustered TDMA (PACT)
  - Divide the TDMA structure into control slot and data slot.
  - Hard to maintain the cluster when there are mobile nodes.
MAC Scheme (Cont.)

Other solutions

- Sensor-MAC (SMAC)
  - Nodes periodically sleep.
  - A node sleeps during transmission period of other nodes.
  - Not suitable for time-critical applications.
Architecture for a WSN

Special addressing requirement
- Local unique addresses
- Data-centric
- *Example: Each node has an unique number.*

Attribute-based naming architecture
- Data is named by one or more attributes.
- *Example: Each node is distinguished by an attribute – GPS sensors are practical for this.*
An address-free architecture (AFA)

**Advantage**
- Randomly select probabilistically unique identifier for each transaction.
- Spatial locality.
- Temporal locality.

**Drawback**
- Not applicable when static addressing of nodes is needed.
- Identifier conflict.
Final Remarks

- Can you think of any applications where a wireless sensor network would be the best solution?

- Do you foresee wireless sensor networks becoming ubiquitous within the next ten years? During your lifetime?