Part I: Introduction to Wireless Sensor Networks

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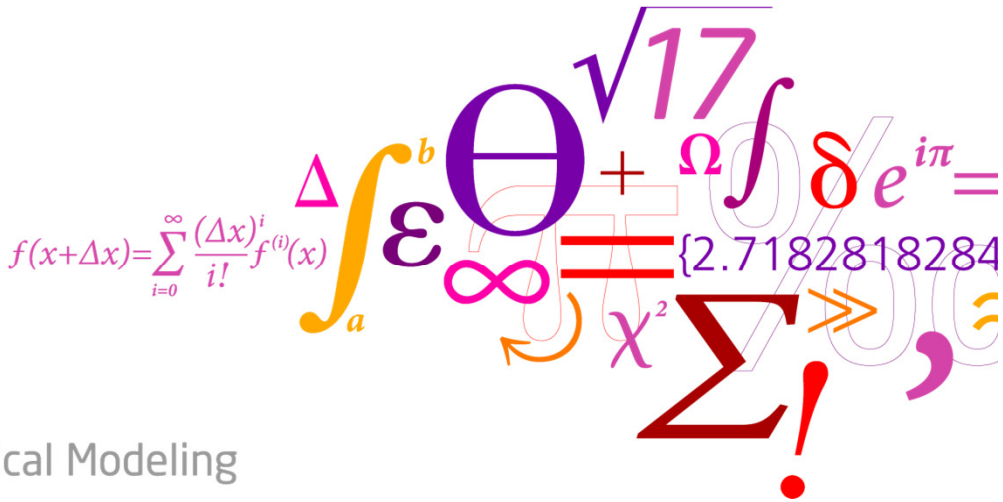

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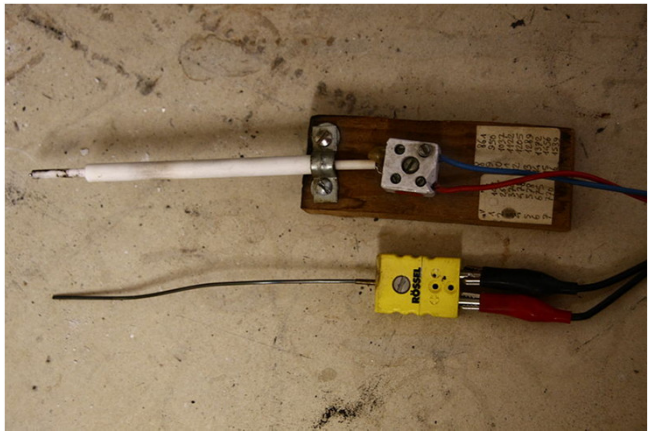
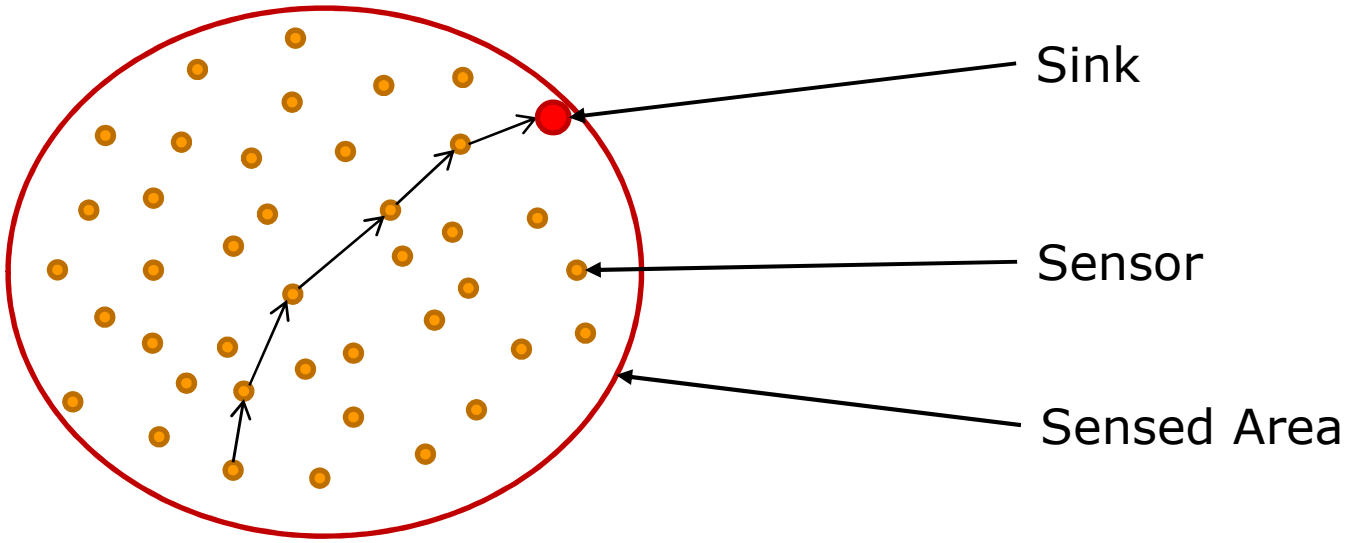
Sensors



Wireless Sensor Networks



Outline

- Wireless Sensor Networks
  - **Types and Topologies**
  - Applications
  - System Issues and Standards
- Energy Harvesting

Types of Nodes

Sensor

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

Sink

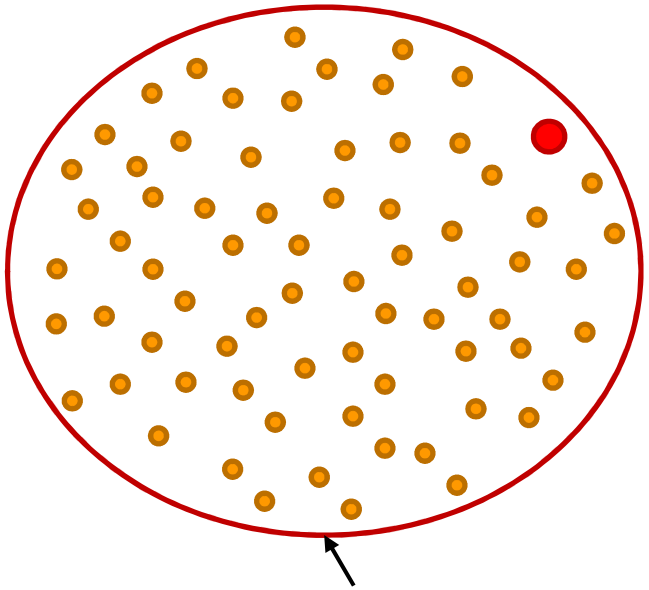
- High resources
- AC power supply
- Internet connection (typically)

Typically *traffic* is generated by the sensors and it is directed to the sink

Unstructured vs. Structured

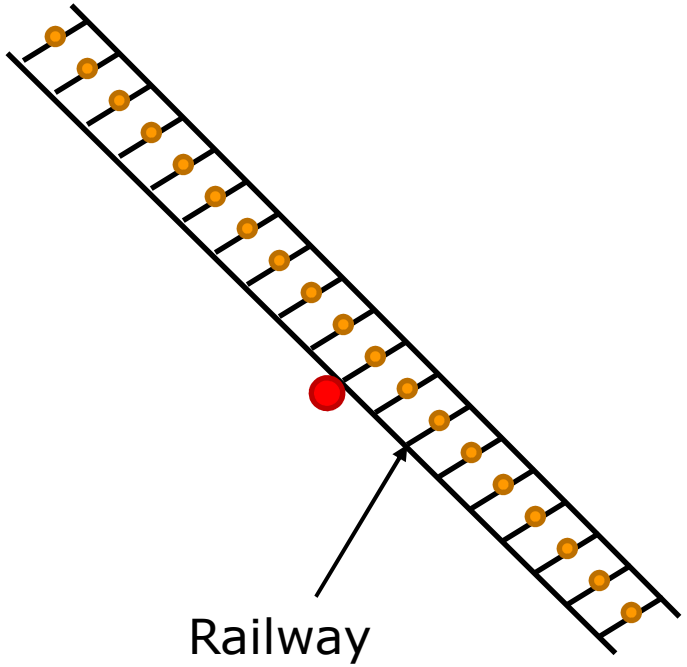
Unstructured

- Dense
- Ad hoc



Structured

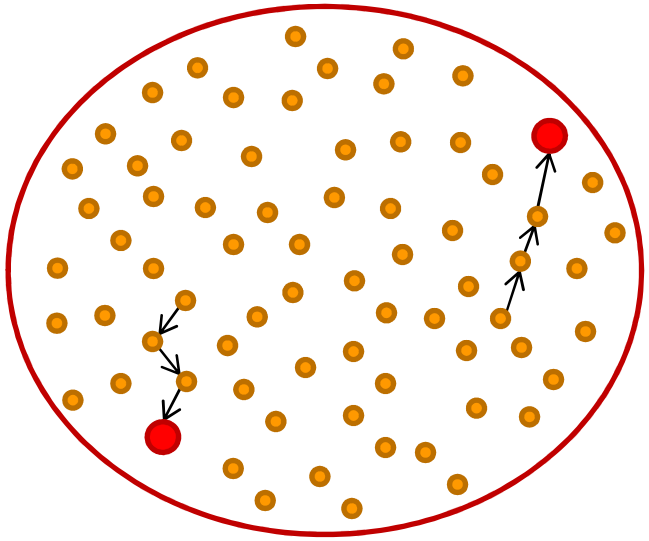
- Fewer sensors
- Strategic positions



Topologies

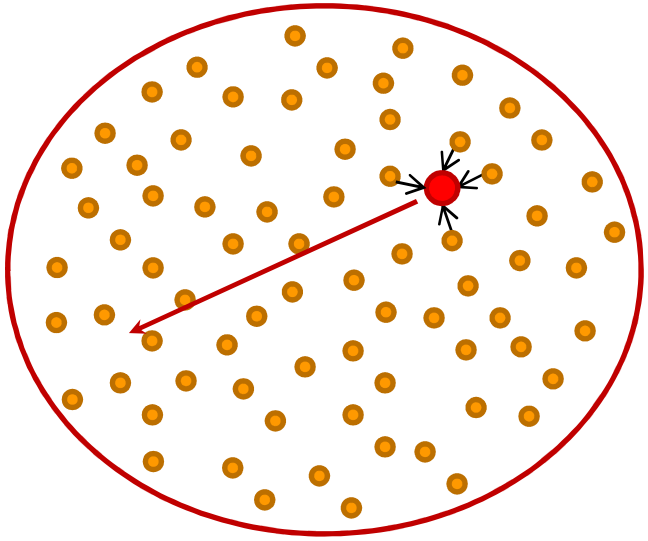
Multi-sink

- Increased cost
- Increased performance
- Reliability



Mobile sinks

- Move and gather data



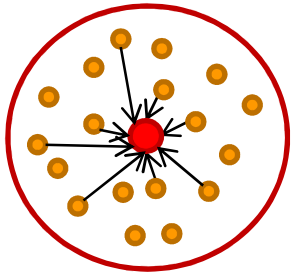
Topologies: Single- vs. Multi-Hop

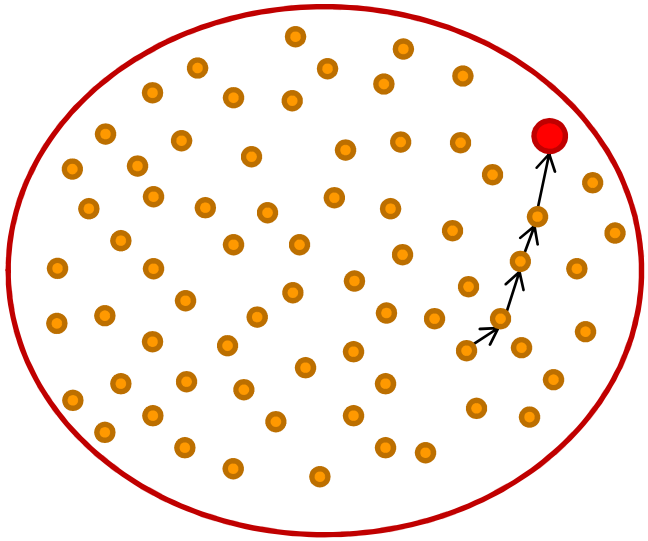
Single-Hop

- Short coverage
- Less challenging
- Higher deployment costs per m^2

Multi-Hop

- Large Coverage
- Challenging

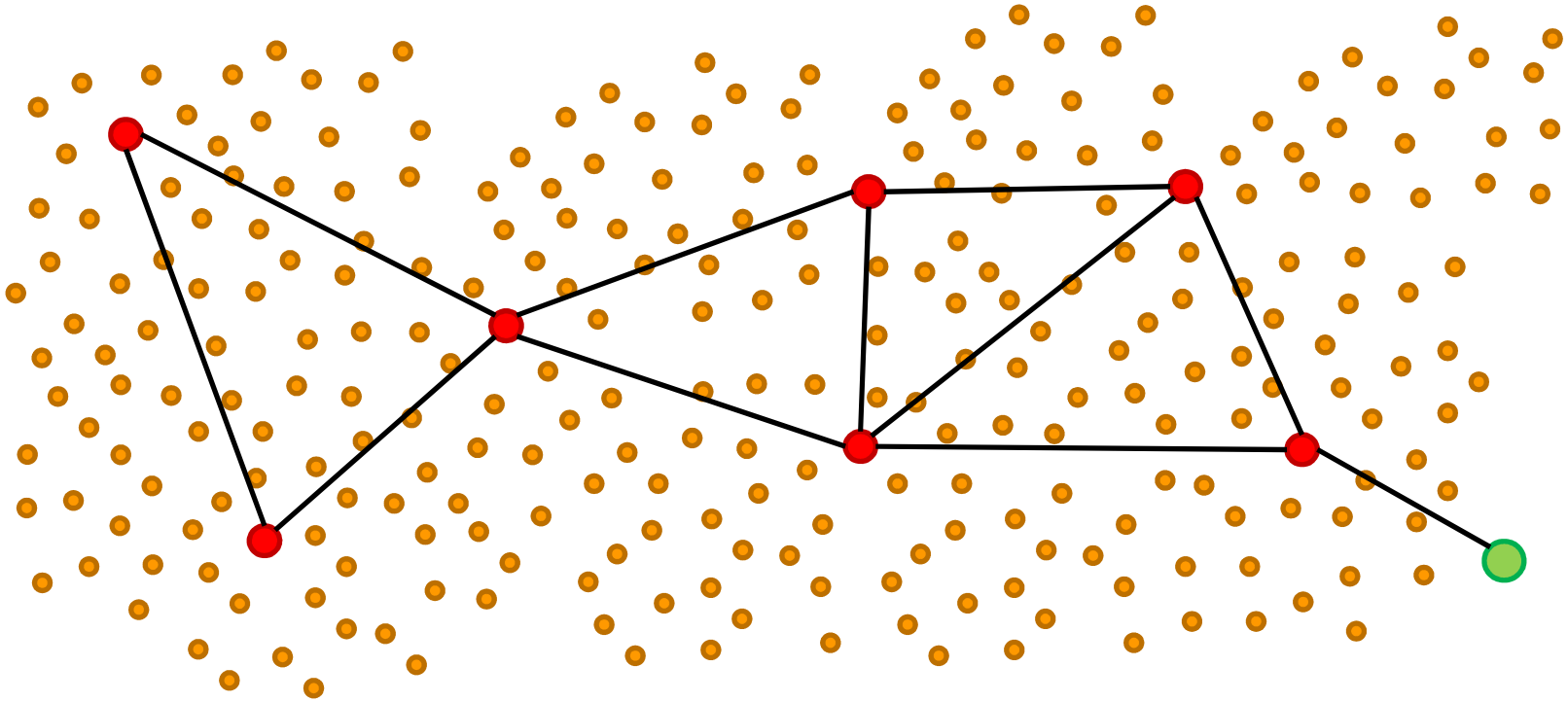




Topologies: Wireless Mesh Network

Very large sensed areas

- Wireless links of several hundreds of meters



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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

Traffic Classification

- Continuous
  - Mainly on monitoring applications
  - Predictable and static
- Event-Driven
  - Mainly on tracking applications
  - Threshold alerts
  - Unpredictable triggering
- Request-Reply
  - Predictable triggering
- Hybrid

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

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Operating System and Standards

- Standards for Low-Rate Wireless Personal Networks (LR-WPN)
  - IEEE 802.15.4
    - Defines the PHY and MAC layers
  - Zigbee
    - Defines the NET and APP layers
- TinyOS, Contiki
  - Operating systems designed for sensor networks

Challenges: Networking

Networking

- Efficient routing (i.e. path selection) in mutli-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)
- Known problem of distributed systems
    - Typical solutions are unsuitable due to the limited resources

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Energy Harvesting

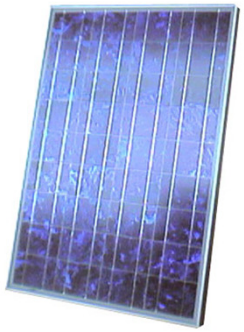
- Battery-powered WSNs
  - Sacrifice performance for lower energy consumption
  - Eventually will die and need battery replacement
    - Often not even possible (e.g. underground sensors)
- Energy-Harvesting WSNs
  - Extracting energy from the environment
  - Infinite lifetime but energy not always available
    - Energy sources have spatiotemporal variations
  - Batteries operate as energy buffers

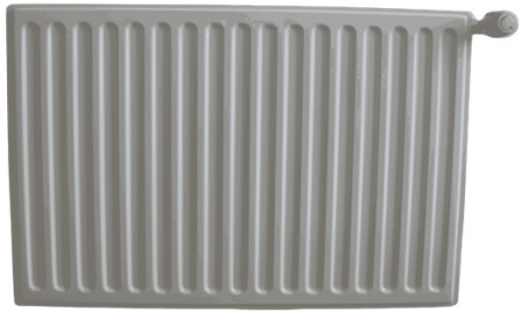
Classification of Energy Availability

- Uncontrollable but predictable
  - E.g. Solar energy
- Uncontrollable and unpredictable
  - E.g. Vibrations in an indoor environment
- Fully controllable
  - E.g. Flush-lights used to generate energy
- Partially controllable
  - E.g. A deployed energy source

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
  - Blood flow and breathing
  - Vibrations
- Acoustic noise
  - High noise levels (e.g. concerts)





Design Objectives

Battery-Based 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