Wireless Sensor Networks

3. Overview

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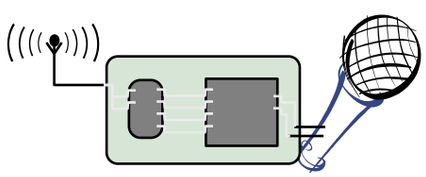
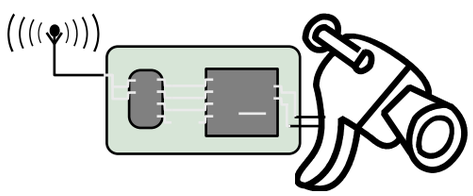
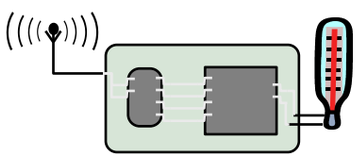
MANET vs. WSN

- In common: Self-organization, energy efficiency, (often) wireless multi-hop
- Differences
  - Applications, equipment: MANETs more powerful (read: expensive) equipment assumed, often “human in the loop”-type applications, higher data rates, more resources
  - Application-specific: WSNs depend stronger on application specifics; MANETs comparably uniform
  - Environment interaction: core of WSN, absent in MANET
  - Scale: WSN might be much larger (although contestable)
  - Energy: WSN tighter requirements, maintenance issues
  - Dependability/QoS: in WSN, individual node may be dispensable (network matters), QoS different because of different applications
  - Data centric vs. id-centric networking
  - Mobility: different mobility patterns like (in WSN, sinks might be mobile, usual nodes static)

Roles of Participants in WSN

- Sources of data: Measure data, report them “somewhere”
  - Typically equip with different kinds of actual sensors

- Sinks of data: Interested in receiving data from WSN
  - May be part of the WSN or external entity, PDA, gateway, …
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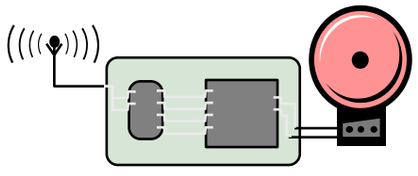
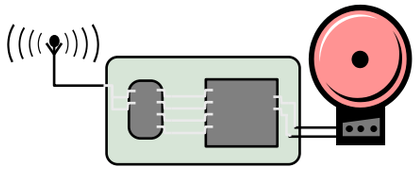
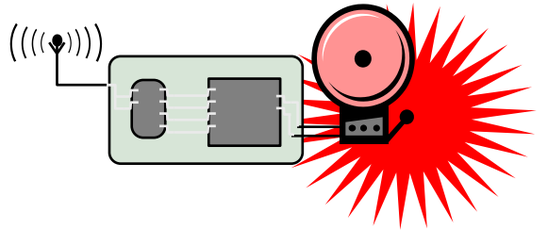



- Actuators: Control some device based on data, usually also a sink

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Structuring WSN Application Types

- Interaction patterns between sources and sinks classify application types
  - Event detection: Nodes locally detect events (maybe jointly with nearby neighbors), report these events to interested sinks
    - Event classification additional option
  - Periodic measurement
  - Function approximation: Use sensor network to approximate a function of space and/or time (e.g., temperature map)
  - Edge detection: Find edges (or other structures) in such a function (e.g., where is the zero degree border line?)
  - Tracking: Report (or at least, know) position of an observed intruder (“pink elephant”)

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Deployment Options for WSN

- How are sensor nodes deployed in their environment?
  - Dropped from aircraft ⇒ Random deployment
    - Usually uniform random distribution for nodes over finite area is assumed
    - Is that a likely proposition?
  - Well planned, fixed ⇒ Regular deployment
    - E.g., in preventive maintenance or similar
    - Not necessarily geometric structure, but that is often a convenient assumption
  - Mobile sensor nodes
    - Can move to compensate for deployment shortcomings
    - Can be passively moved around by some external force (wind, water)
    - Can actively seek out “interesting” areas

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Maintenance Options

- Feasible and/or practical to maintain sensor nodes?
  - E.g., to replace batteries?
  - Or: unattended operation?
  - Impossible but not relevant? Mission lifetime might be very small

- Energy supply?
  - Limited from point of deployment?
  - Some form of recharging, energy scavenging from environment?
    - E.g., solar cells

Characteristic Requirements for WSNs

- Type of service of WSN
  - Not simply moving bits like another network
  - Rather: provide answers (not just numbers)
  - Issues like geographic scoping are natural requirements, absent from other networks
- Quality of service
  - Traditional QoS metrics do not apply
  - Still, service of WSN must be “good”: Right answers at the right time
- Fault tolerance
  - Be robust against node failure (running out of energy, physical destruction, …)
- Lifetime
  - The network should fulfill its task as long as possible – definition depends on application
  - Lifetime of individual nodes relatively unimportant
  - But often treated equivalently

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Characteristic Requirements for WSNs

- Scalability
  - Support large number of nodes
- Wide range of densities
  - Vast or small number of nodes per unit area, very application-dependent
- Programmability
  - Re-programming of nodes in the field might be necessary, improve flexibility
- Maintainability
  - WSN has to adapt to changes, self-monitoring, adapt operation
  - Incorporate possible additional resources, e.g., newly deployed nodes

Required Mechanisms to Meet Requirements

- Multi-hop wireless communication
- Energy-efficient operation
  - Both for communication and computation, sensing, actuating
- Auto-configuration
  - Manual configuration just not an option
- Collaboration & in-network processing
  - Nodes in the network collaborate towards a joint goal
  - Pre-processing data in network (as opposed to at the edge) can greatly improve efficiency

Required Mechanisms to Meet Requirements

- Data centric networking
  - Focusing network design on data, not on node identities (id-centric networking)
  - To improve efficiency
- Locality
  - Do things locally (on node or among nearby neighbors) as far as possible
- Exploit tradeoffs
  - E.g., between invested energy and accuracy

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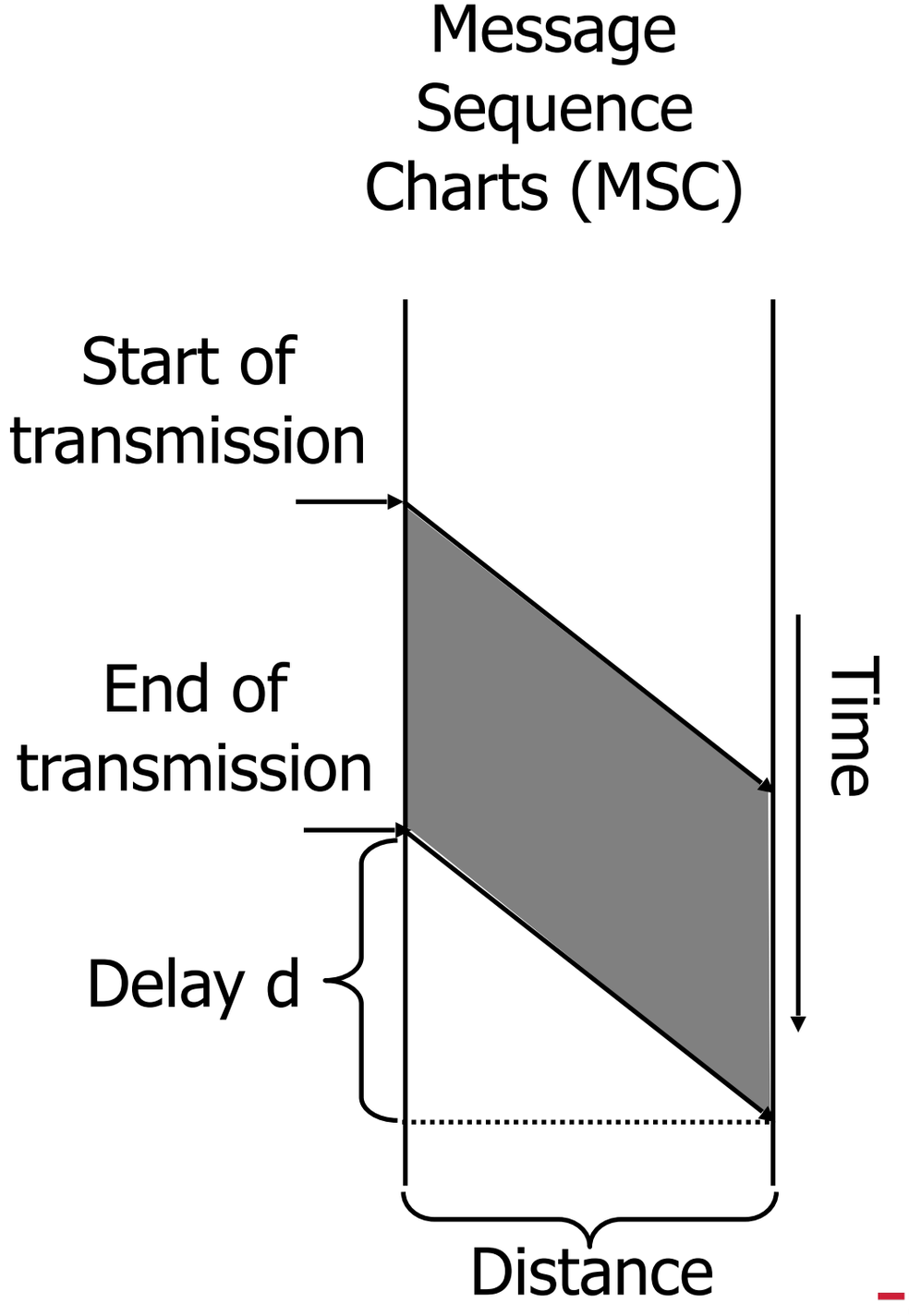
Enabling Technologies for WSN

- Cost reduction
  - For wireless communication, simple microcontroller, sensing, batteries
- Miniaturization
  - Some applications demand small size
  - “Smart dust” as vision
- Energy harvesting
  - Recharge batteries from ambient energy (light, vibration, …)

Signals propagate in medium, store data

- Signals traveling in a medium take time to reach destination – delay d
  - Depends on distance and propagation speed in transmission medium
- To represent one or several bits, a signal extending in time is needed – duration of transmission
  - Determined by rate r and data size
- During time d, r*d bits are generated
  - Stored in the medium



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Handling errors

- Transmission errors
  - Signals are mutilated, not correctly converted to (intended) bits
  - Local issue
- Packets are missing
  - Local or end-to-end issue
- Overload problems
  - Flow control: Fast sender overruns slow receiver
  - Congestion control: Receiver would be fast enough, but sender injects more packets into network than network is able to handle
- Where and how to handle these errors?

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Typical examples of services

- Datagram service
  - Unit of data are messages
  - Correct, but not necessarily complete or in order
  - Connection-less
  - Usually insecure/not dependable, not confirmed

- Reliable byte stream
  - Byte stream
  - Correct, complete, in order, confirmed
  - Sometimes, but not always secure/dependable
  - Connection-oriented

- Almost all possible combinations are conceivable!

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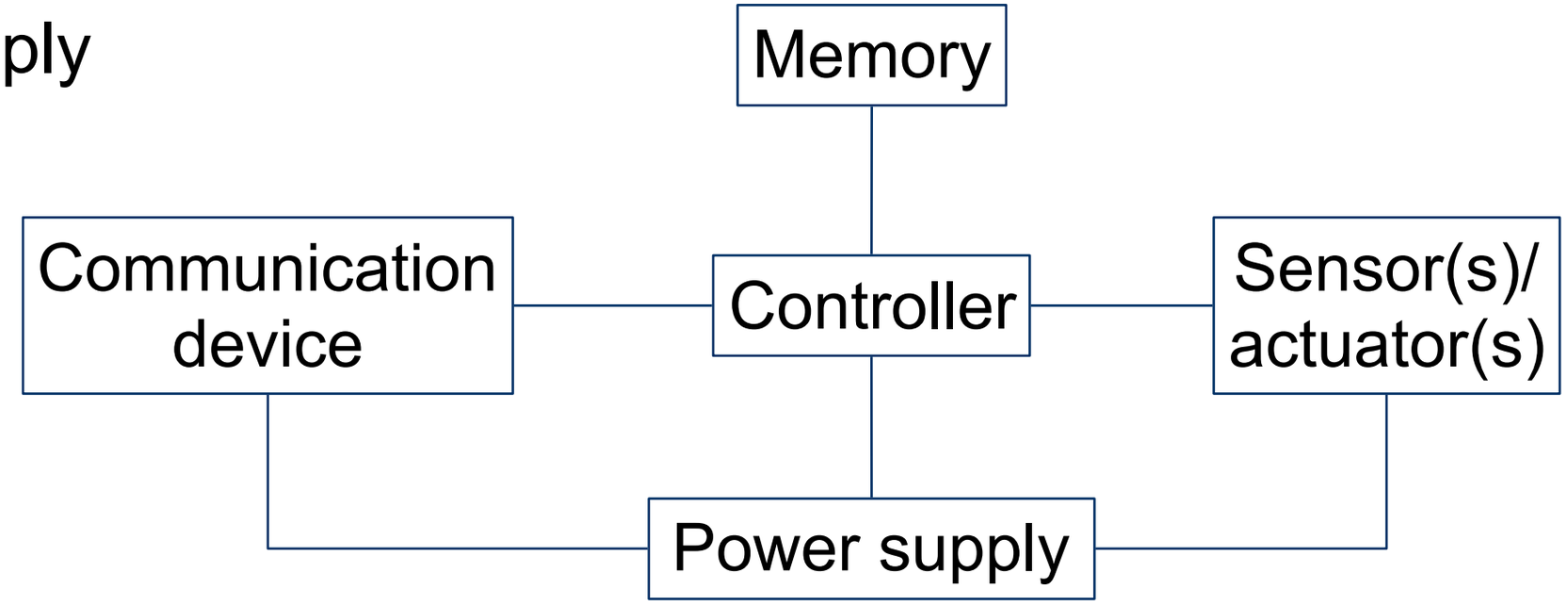
Sensor node architecture

- Main components of a WSN node
  - Controller
  - Communication device(s)
  - Sensors/actuators
  - Memory
  - Power supply



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Transceiver characteristics

- Capabilities
  - Interface: bit, byte, packet level?
  - Supported frequency range?
    - Typically, somewhere in 433 MHz – 2.4 GHz, ISM band
  - Multiple channels?
  - Data rates?
  - Range?
- Energy characteristics
  - Power consumption to send/receive data?
  - Time and energy consumption to change between different states?
  - Transmission power control?
  - Power efficiency (which percentage of consumed power is radiated?)

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