Wireless Sensor Networks

2nd Lecture

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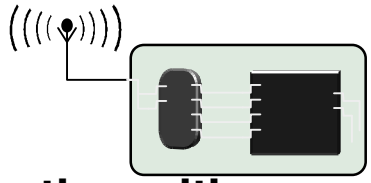
- **Participants in the previous examples were devices close to a human user, interacting with humans**



- **Alternative concept:**

  Instead of focusing interaction on humans, focus on interacting with *environment*

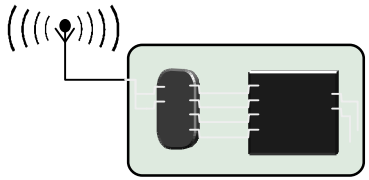
  – Network is ***embedded*** in environment

  – Nodes in the network are equipped with ***sensing*** and ***actuation*** to measure/influence environment

  – Nodes process information and communicate it wirelessly

⇒ *Wireless sensor networks* **(WSN)**

  – Or: ***Wireless sensor & actuator networks*** (WSAN)



Roles of Participants in WSN

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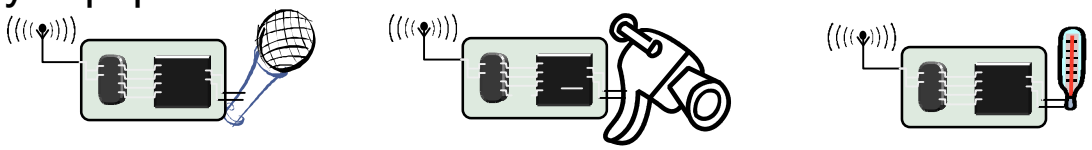
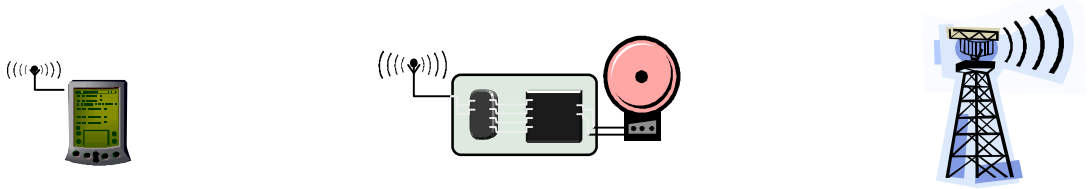
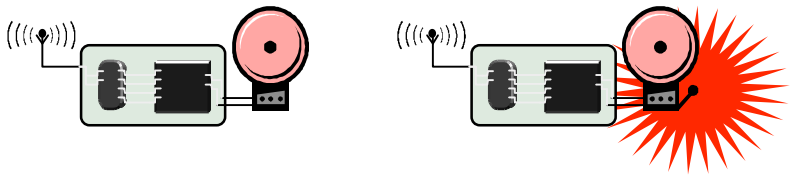
- *Sources* **of data: Measure data, report them "somewhere"**
  - Typically equip with different kinds of actual sensors



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



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



Structuring WSN Application Types

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- *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”)

Deployment Options for WSN

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- **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

Maintenance Options

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- **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

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- **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

Characteristic Requirements for WSNs

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- **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

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- **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

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- **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

MANET vs. WSN

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- **Many commonalities: Self-organization, energy efficiency, (often) wireless multi-hop**
- **Many 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 much 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)

Enabling Technologies for WSN

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- **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, …)

Conclusion

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- MANETs and WSNs are challenging and promising system concepts
- Many similarities, many differences
- Both require new types of architectures & protocols compared to "traditional" wired/wireless networks
- In particular, application-specificness is a new issue

Thank you

(and thanks go also to Holger Karl for providing slides)

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