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

- **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

- 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”)

Wireless Sensor Networks

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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
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
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
MANET vs. WSN

- 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

- **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

- 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)