Wireless Sensor Networks

1st Lecture

24.10.2006

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

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Organization

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- **Web-page**
  - `http://cone.informatik.uni-freiburg.de/teaching/lecture/wsn-w06/`
- **Lectures**
  - Tuesdays, 2-4 pm, c.t. SR 01-018, Building 101
  - Wednesdays, 2-3 pm, c.t. SR 01-018, Building 101
- **Room change:**
  - tomorrow: SR 101-01-016
  - from next week on: HS 026, 101
- **Exercise classes**
  - Wednesdays, 3-4 pm, c.t. SR 01-018, Building 101
  - Start: 08.11.2006
  - Tutors:
    - Chia-Ching Ooi (ooi (at) informatik.uni-freiburg.de)
    - Faisal Aslam (asmal (at) informatik.uni-freiburg.de)
- **Exercises**
  - Appear every Friday on the Web page
  - Solved by the students
  - Solution be discussed and presented by the students during the exercise class

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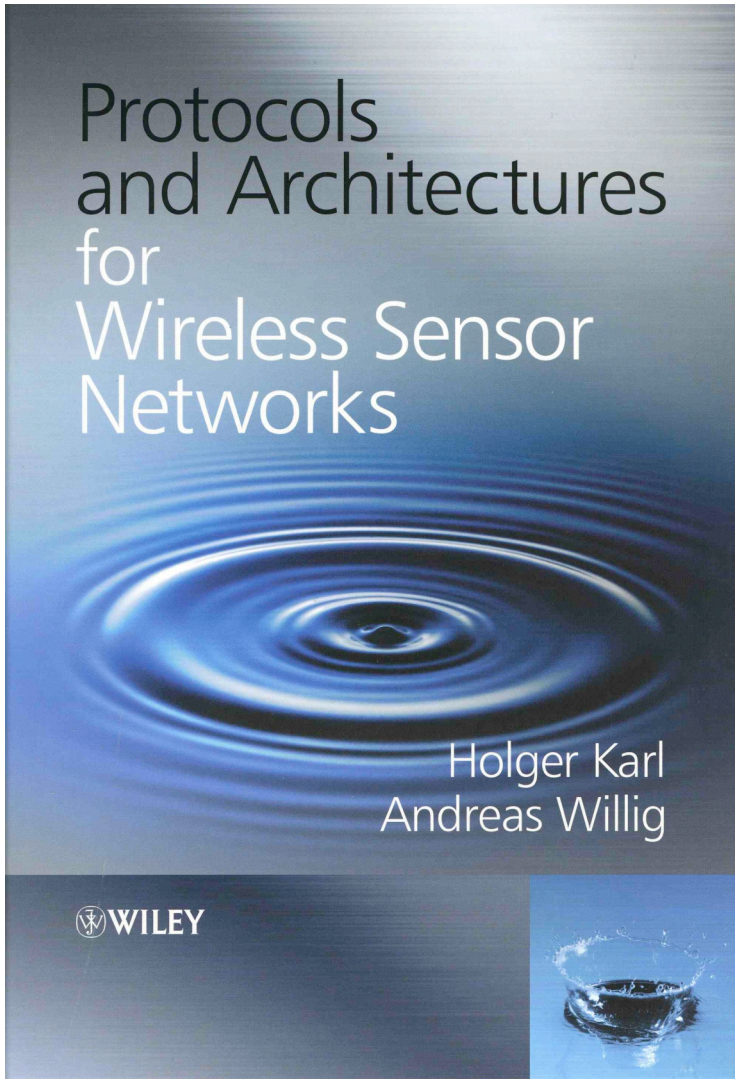
- **Exam**
  - Under 15 participants: oral exams
  - More than 16 participants: written exam
- **Time**
  - Oral: ask for an appointment on 27./28.02.2006
  - Written exam, if any: 28.02.2006, 2pm
- **Materials**
  - Powerpoint/PDF slides
    - 1h before the lecture on the web-page
  - Lecturnity videos
    - on the web-page and in the *lecturnity* web-pages
  - Book
    - Holger Karl and Andreas Willig: *Protocols and Architectures for Wireless Sensor Networks*

Literature I

- **Holger Karl and Andreas Willig**
  - *Protocols and Architectures for Wireless Sensor Networks*
  - Wiley, 2005
- **Contents**
  - Architecture and communication protocols
  - Relationships of different protocol and architectural decisions
- **This is the underlying book for this lecture**



Literature II

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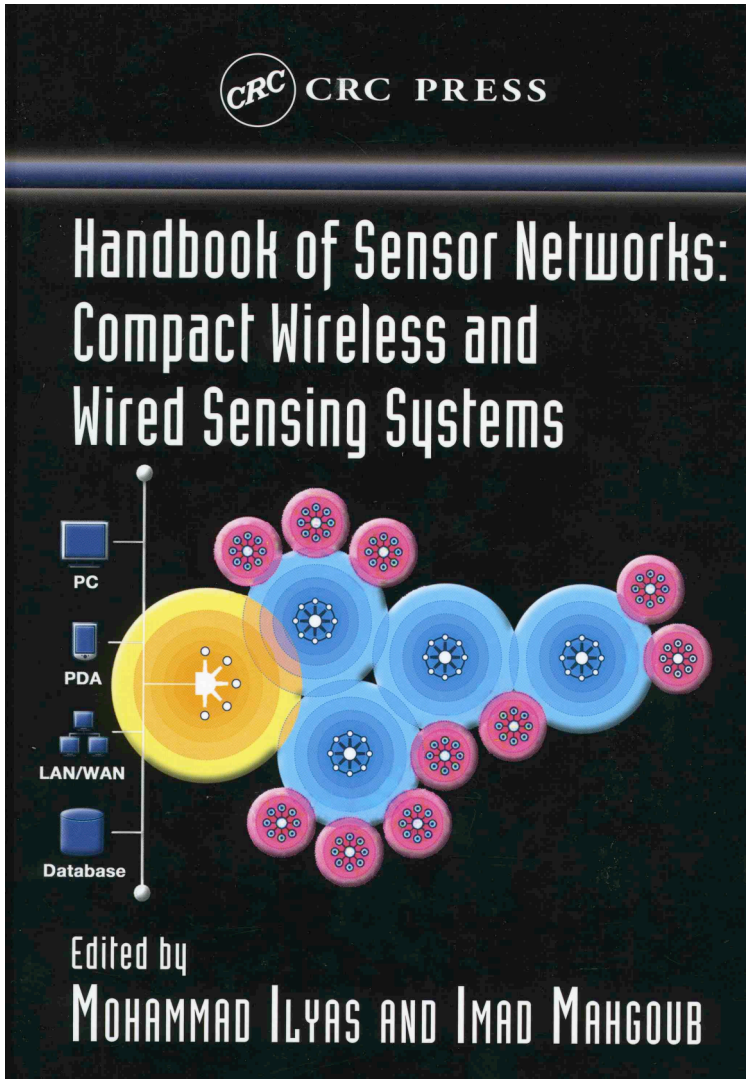
- **Editors: Ilyas and Mahgoub**
  - *Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems*
  - CRC Press, 2005
- **Collection of specialized chapters on sensor networks**
  - Hard too read for the beginner
  - Detailed description of special topics in each chapter written by specialists in the field



Literature III

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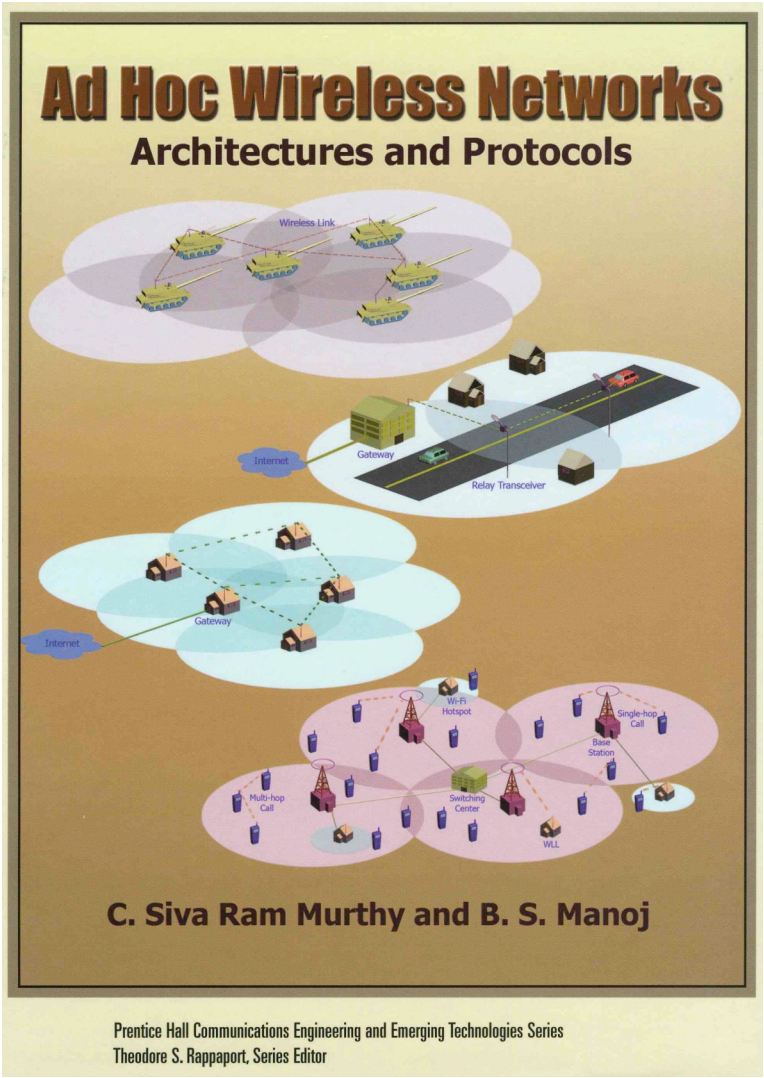
- **Murthy and Manoj**
  - *Ad Hoc Wireless Networks, Architectures and Protocols*
  - Pearson/Prenticie Hall, 2004
- **Comprehensive Monography on Wireless Networking**
  - with a chapter dedicated to sensor networks
- **Recommended as one book covering early all aspects of wireles communication**
  - 802.3, 802.11, HiperLAN, GSM, ATM, WATM, MobileIP, MANET, MAC for Wireless, Routing and Multicast Routing in MANETs, Transport layer, QoS, Energy Management, Sensor Networks, Hybrid Networks



Literature IV

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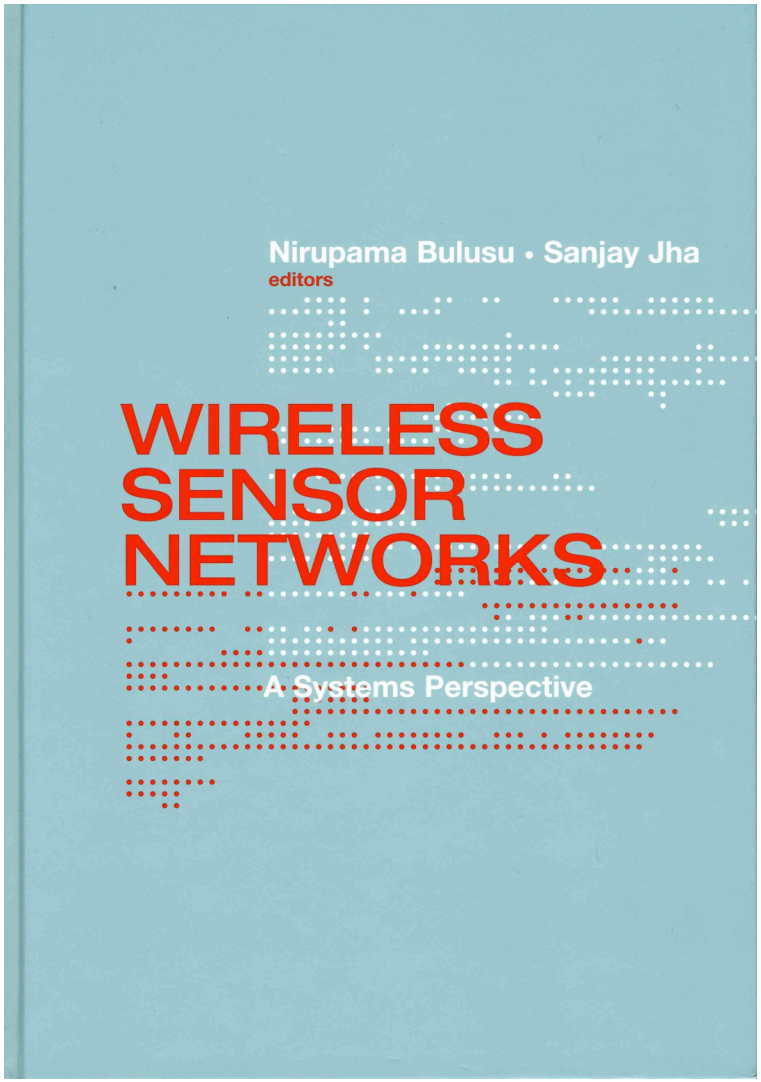
- **Editors: Bulusu and Jha**
  - *Wireless Sensor Networks, A Systems Perspective*
  - Artech House, 2005
- **Short introduction to wireless sensor networks**
- **Enumeration of systems and approaches**
- **Does not show all technical details**



Literature V

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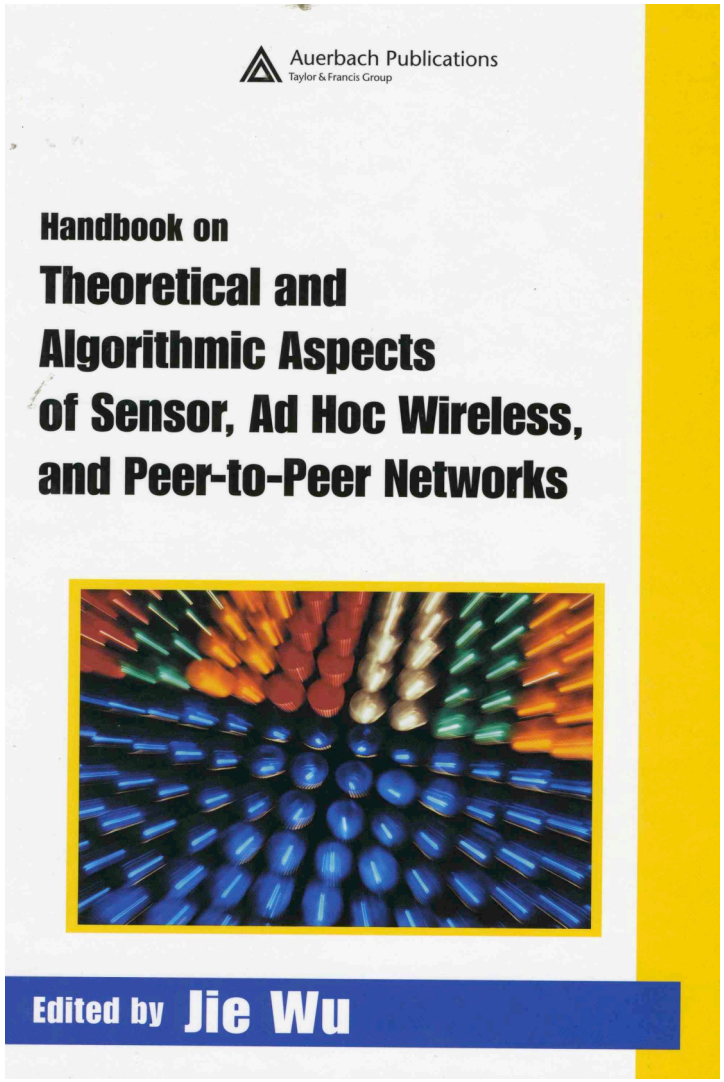
- **Editor: Jie Wu**
  - *Handbook on Theoretical and Algorithmic Aspects of Sensor, Ad Hoc Networks and Peer-to-Per Networks*
  - Auerbach, 2005
- **16 chapters on sensor networks written by the experts in the field**
- **Can also be recommended for the peer-to-peer network section**



Literature VI

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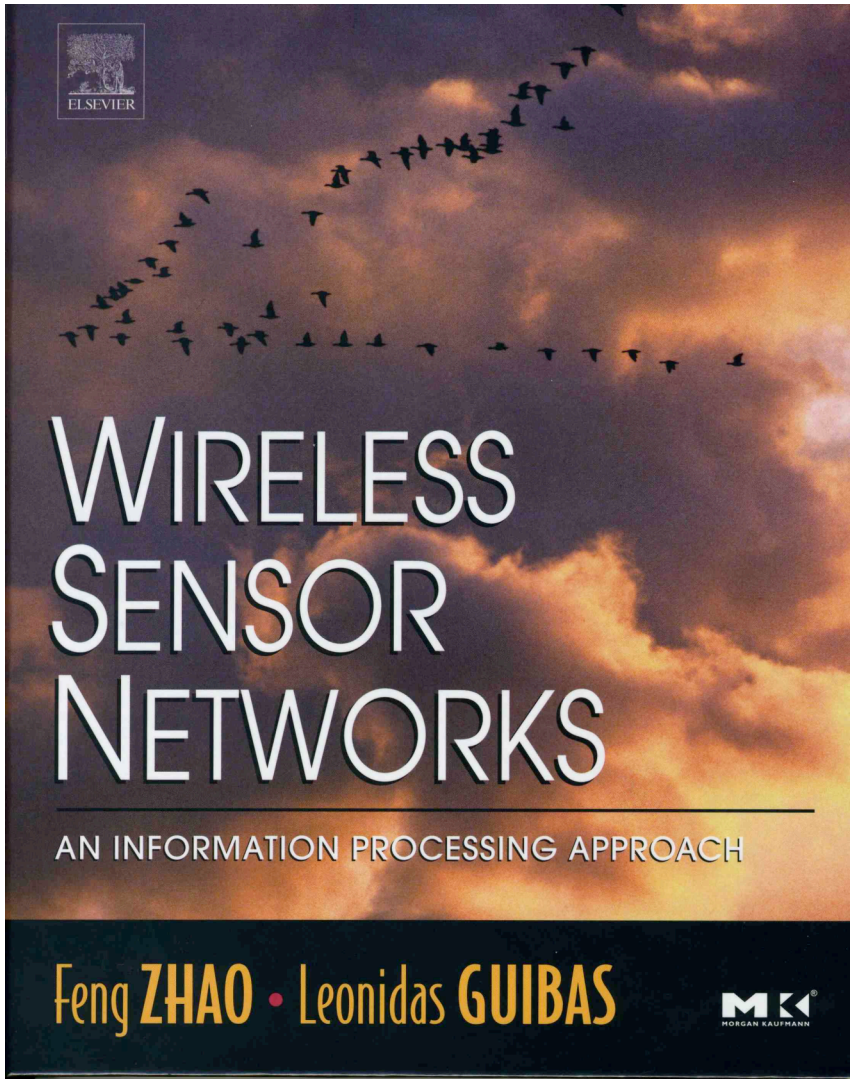
- **Zhao, Guibas**
  - *Wireless Sensor Networks - An Information Processing Approach*
  - Morgan Kaufmann, 2004
- **Algorithmic view at wireless sensor networks**
- **Topics:**
  - Localization
  - MAC, Infrastructure
  - Sensor tasking and control
  - Sensor network databases
  - Network platforms and tools



Infrastructure-based Wireless Networks

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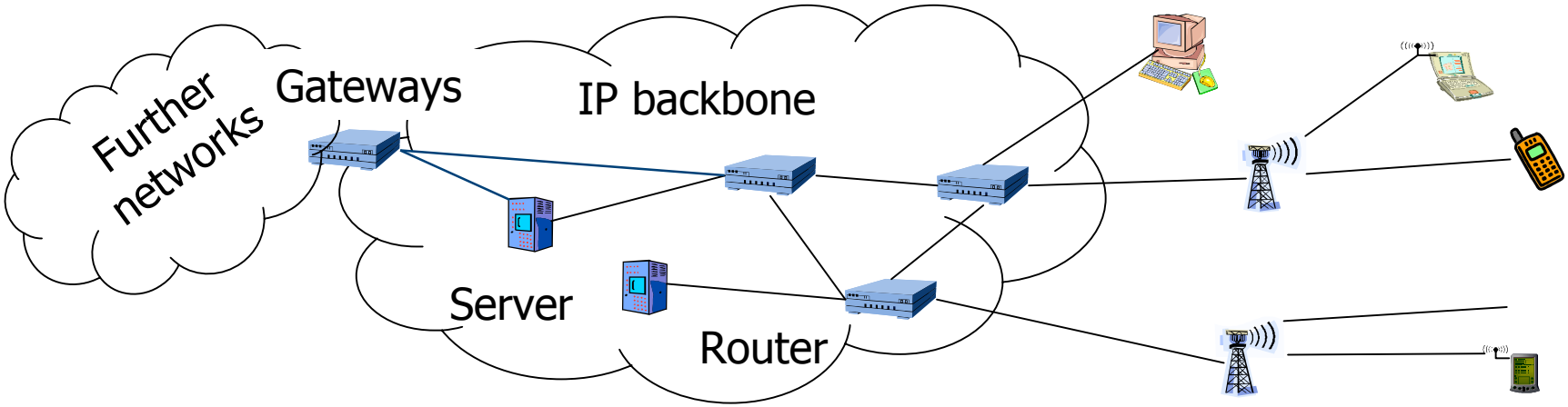
- **Typical wireless network: Based on infrastructure**
  - E.g., GSM, UMTS, …
  - Base stations connected to a wired backbone network
  - Mobile entities communicate wirelessly to these base stations
  - Traffic between different mobile entities is relayed by base stations and wired backbone
  - Mobility is supported by switching from one base station to another
  - Backbone infrastructure required for administrative tasks



Infrastructure-based Wireless Networks – Limits?

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- **What if …**
  - No infrastructure is available?
    - E.g., in disaster areas, under-developed countries
  - It is too expensive/inconvenient to set up?
    - E.g., in remote, large construction sites
  - There is no time to set it up?
    - E.g. in military operations

Possible Applications for Infrastructure-free Networks

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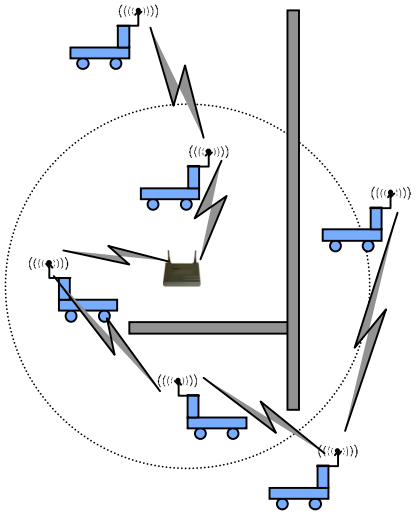
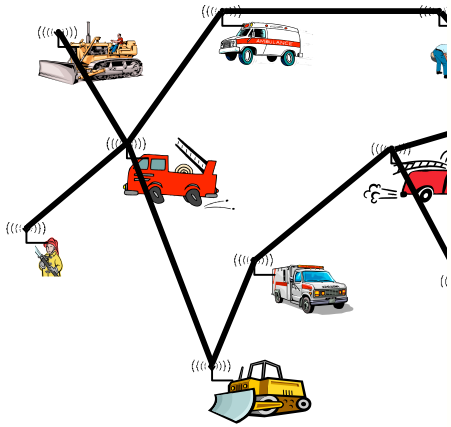
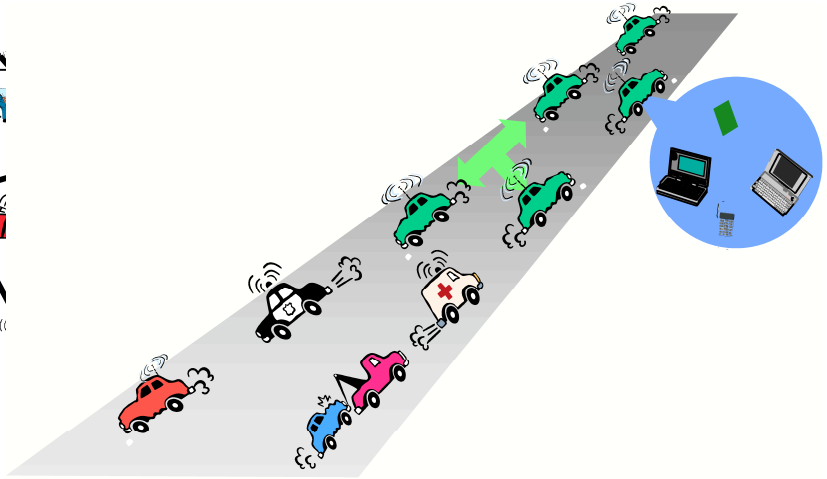
- Factory floor automation



- Disaster recovery



- Car-to-car communication



- Military networking
- Search-and-rescue
- Personal area networking (watch, glasses, PDA, medical appliance, …)
- …

Solution: (Wireless) Ad hoc Networks

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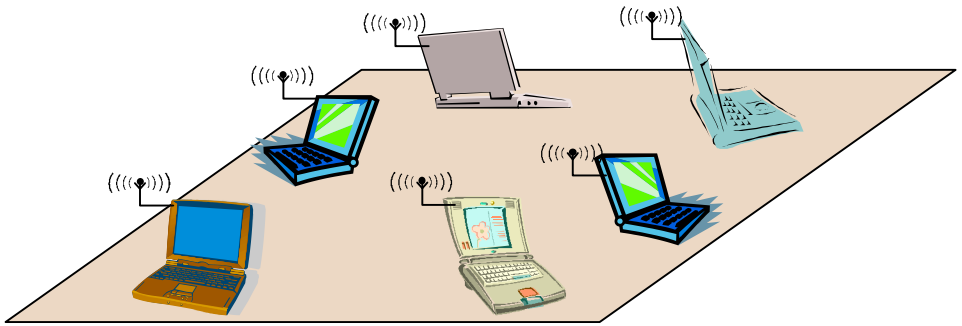
- **Try to construct a network without infrastructure, using networking abilities of the participants**
  - This is an ***ad hoc network*** – a network constructed "for a special purpose"

- **Simplest example: Laptops in a conference room – a** *single-hop ad hoc network*



Problems & Challenges for Ad hoc Networks

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- **Without a central infrastructure, things become much more difficult**
- **Problems are due to**
  - Lack of central entity for organization available
  - Limited range of wireless communication
  - Mobility of participants
  - Battery-operated entities

No Central Entity → Self-Organization

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- **Without a central entity (like a base station), participants must organize themselves into a network (*self-organization*)**
- **Pertains to (among others):**
  - Medium access control – no base station can assign transmission resources, must be decided in a distributed fashion
  - Finding a route from one participant to another

Limited Range → Multi-Hopping

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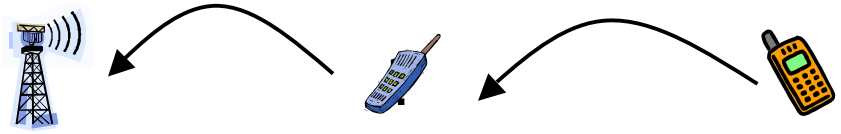
- **For many scenarios, communication with peers outside immediate communication range is required**
  - Direct communication limited because of distance, obstacles, …
  - Solution: ***multi-hop network***



Mobility ⇒ Suitable, Adaptive Protocols

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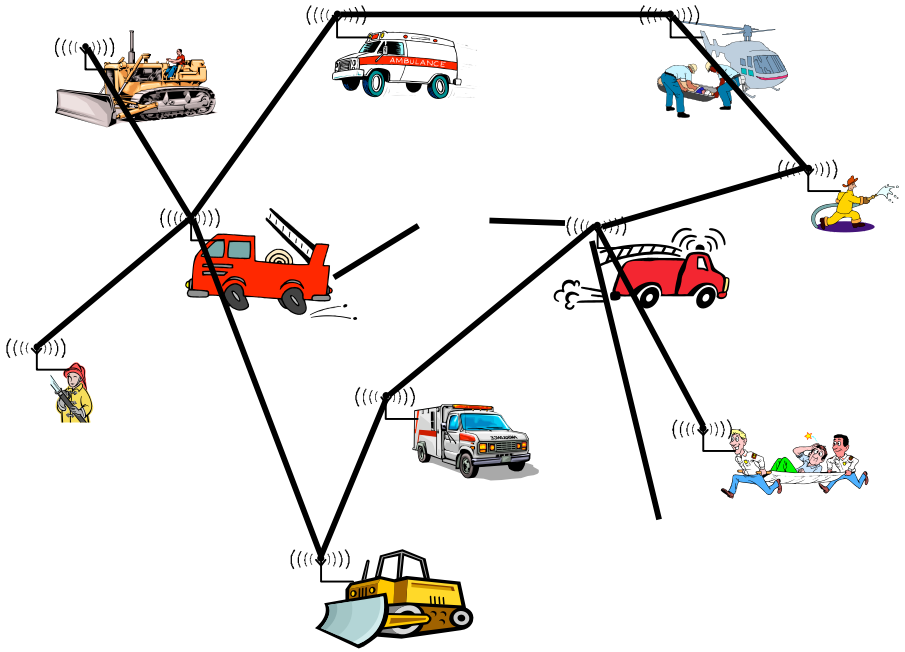
- **In many ad hoc network applications, participants move around**
  - In cellular network: simply hand over to another base station

- **In** *mobile ad hoc networks (MANET)***:**
  - Mobility changes neighborhood relationship
  - Must be compensated for
  - E.g., routes in the network have to be changed



- **Complicated by scale**
  - Large number of such nodes difficult to support

Battery-Operated Devices ⇒ Energy-Efficient Operation

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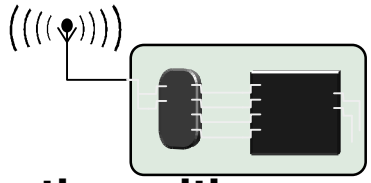
- **Often participants in an ad hoc network draw energy from batteries**
- **Desirable: long run time for**
  - Individual devices
  - Network as a whole
- ⇒ **Energy-efficient networking protocols**
  - E.g., use multi-hop routes with low energy consumption (energy/bit)
  - E.g., take available battery capacity of devices into account
  - How to resolve conflicts between different optimizations?

- **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*

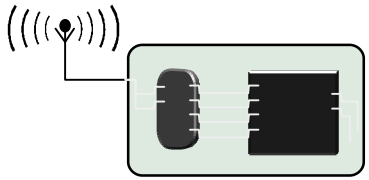
  – Network is ***embedded*** in environment

  – 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)



Application for Wireless Sensor Networks?

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- This place is supposed to be empty.

WSN Application Examples

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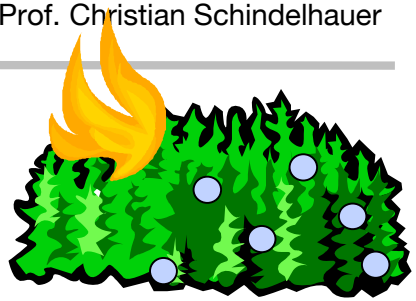

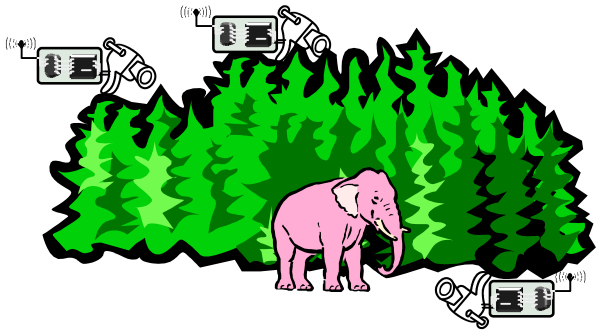

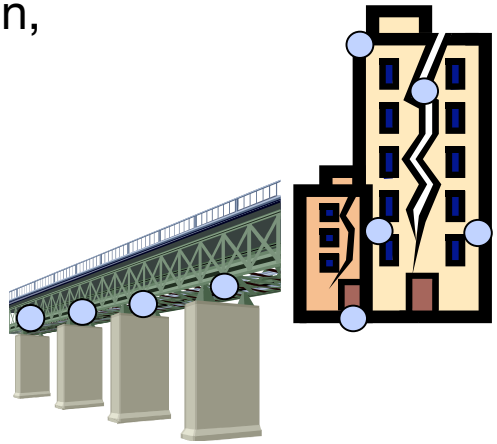

- **Disaster relief operations**
  - Drop sensor nodes from an aircraft over a wildfire
  - Each node measures temperature
  - Derive a “temperature map”
- **Biodiversity mapping**
  - Use sensor nodes to observe wildlife
- **Tracking of wild animals**
  - e.g. Zebras, black storks
- **Intelligent buildings (or bridges)**
  - Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control
  - Needs measurements about room occupancy, temperature, air flow, …
  - Monitor mechanical stress after earthquakes
- **Environmental Measuring**
  - E.g. currents in the Gulf stream

WSN Application Scenarios

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- **Facility management**
  - Intrusion detection into industrial sites
  - Control of leakages in chemical plants, …
- **Machine surveillance and preventive maintenance**
  - Embed sensing/control functions into places no cable has gone before
  - E.g., tire pressure monitoring
- **Precision agriculture**
  - Bring out fertilizer/pesticides/irrigation only where needed
- **Medicine and health care**
  - Post-operative or intensive care
  - Long-term surveillance of chronically ill patients or the elderly

WSN Application Scenarios

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- **Logistics**
  - Equip goods (parcels, containers) with a sensor node
  - Track their whereabouts – ***total asset management***
  - Note: passive readout might suffice – compare RF IDs
- **Telematics**
  - Provide better traffic control by obtaining finer-grained information about traffic conditions
  - ***Intelligent roadside***
  - Cars as the sensor nodes

Thank you

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

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