TIWSNE – Wireless Sensor Networks and Electronics – (2015-Q4)

Lecture 1

Introduction & WSN Applications

Jens Kargaard Madsen

(Email: jkm@eng.au.dk; Room E228)

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Lecture plan of Today

- Course overview
- Motivation for WSN
- WSN Applications
- WSN Characteristics & Requirements

Lecture dream-team

Qi Zhang, MScEE, PhD
Assoc. Prof.,
Communication Systems group
Department of Engineering
qz@eng.au.dk, office E314

Michael Aalrøe, MScIT,
Assoc. Prof.,
Embedded Systems group
Aarhus Univ School of Engineering
ma@ase.au.dk, office E301B

John Rohde, MScEE, PhD
Assoc. Prof.
Electronics group
Department of Engineering
jr@ase.au.dk, office E318

Jens K. Madsen, MScEE, PhD
Docent,
Head of ECE section
Director of MSc Engineering studies
Department of Engineering
jkm@eng.au.dk, office E228

Course Objectives

- The participants will after the course have **insight into wireless sensor networks**, including applications, architectures, protocols and sensor hardware nodes. The course aims to convey a knowledge of design and robust implementation and deployment of wireless sensor networks, such train the participants **to plan and implement wireless sensor networks**.

Course learning outcomes and competences

- ***identify*** and ***describe*** wireless sensor networks, components, and their applications,
- ***explain*** and ***compare*** different wireless sensor networks, architectures and protocols,
- ***explain*** and ***analyse*** power and energy challenges and scavenging methods,
- ***compare*** and ***discuss*** design metrics and constraints,
- ***design*** and ***implement*** wireless sensor networks.

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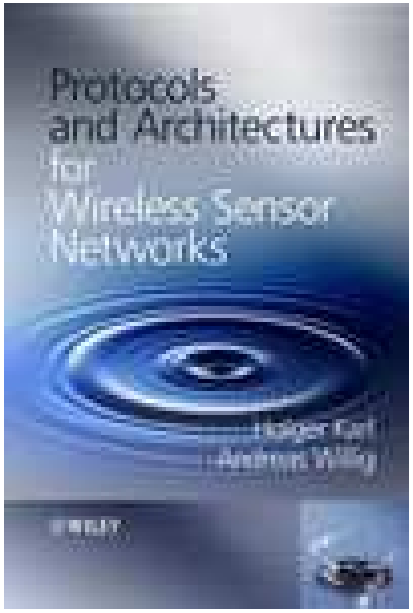
Materials



Holger Karl & Andreas Willig
Protocols and Architectures for Wireless Sensor Networks

Paperback Ed. (ISBN 978-0-470-51923-3)
Wiley 2007

- Notes, Guide lines, weekly notes @ Blackboard (TIWSNE)

Practical information

- Time slots:
  - Lectures (normal)
    - Tuesdays: 08:15-12:00
      - Remark some Tuesdays starts at 10:15
    - Wednesdays: 12:15-14:00
    - See next slides/Blackboard “Lecture plan and preparation” for details
- Class room: 003B, Shannon

Practical information

- Work load per week:
  - 4 hrs lectures + preparation, exercises & project work
- Prerequisites:
  - Digital communications, fundamental electronics and embedded systems and components
- All information's, documentations, announcements etc. will be available via Blackboard (TIWSNE)

Lecture plan

	Time	Lecturer	Lecture content
Lecture 1	14/04 10:15-12:00	JKM	Introduction & WSN applications
Lecture 2	15/04 12:15-14:00	MA/QZ	Introduction to Test bed TelosB, TinyOS and NesC & Presentation of projects
Lecture 3	21/04 10:15-12:00	JKM	HW Nodes & Energy
Lecture 4	22/04 12:15-14:00	MA	More TinyOS & hands on TelosB platform
Lecture 5	28/04 08:15-10:00	MA	More TinyOS & hands on TelosB platform
Lecture 6a	28/04 10:15-12:00	JKM	Energy/Power lab exercise – Grp's 1 to n out of N
Lecture 7	29/04 12:15-14:00	QZ	Network Architecture
Lecture 8	05/05 08:15-10:00	JR	Physical Layer lecture
Lecture 6b	05/05 10:15-12:00	JKM	Energy/Power lab exercise – Grp's n+1 to N out of N
Lecture 9	06/05 12:15-14:00	QZ	MAC protocols
Lecture 10	12/05 10:15-12:00	QZ	Link Layer protocols
Lecture 11	13/05 12:15-14:00	MA/QZ	Project support & status check
Lecture 12	19/05 10:15-12:00	QZ	Networking
Lecture 13	20/05 12:15-14:00	QZ	Transport layer and QoS
Lecture 14	26/05 08:15-12:00	JKM/QZ	Group presentation
Lecture 15	27/05 12:15-14:00	JKM/QZ	Summary & Exam Info

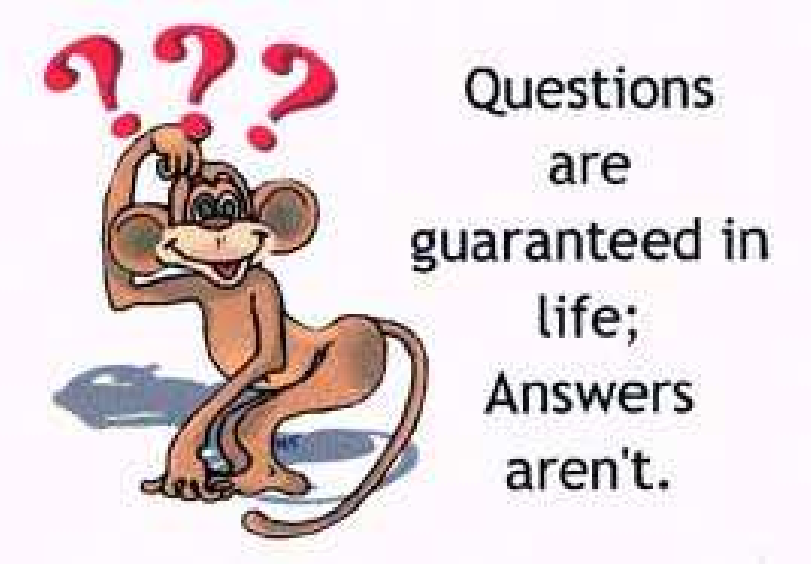
* Might be changes during the quarter – announced on Blackboard

Project work

- Proposals & selection – Week 1
  - Wed 15/4 – project presentations
  - Fri 17/4 – group & selection deadline
    - ~4 per group (~15 groups)
- Design & Implementation – Week 2-7
- Presentation & Report – Week 7
  - Presentation: 26/5 @8:15-12:00
    - 10 mins per group in front of class
  - Report turn-in: Sun-7/6 @23:59 (current plan)
    - ~15 pages

Examination & Evaluation

- Requires completed project, report & presentation
- Individual oral examination (20 mins incl. grading) with no preparation
  - General topic from a list of pre-announced questions (~9)
  - Project
- Grade – an overall grade by use of 7-scale
  - Includes both project report and oral performance (report and question)
  - External censor
- Dates : 17-19/June /2015 (current plan)


???
Questions
are
guaranteed in
life;
Answers
aren't.

Motivation for WSN

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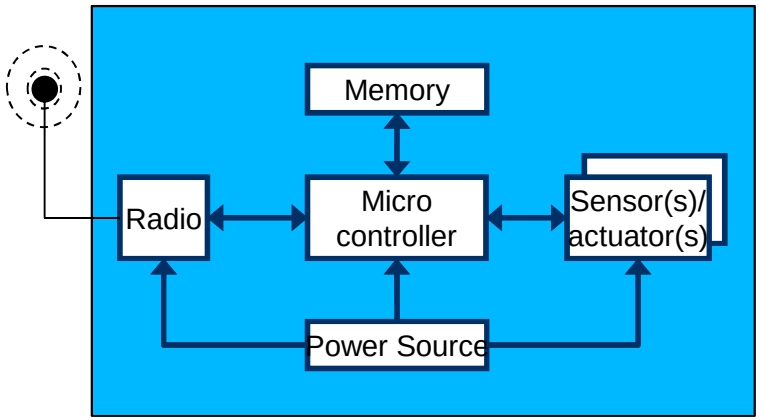
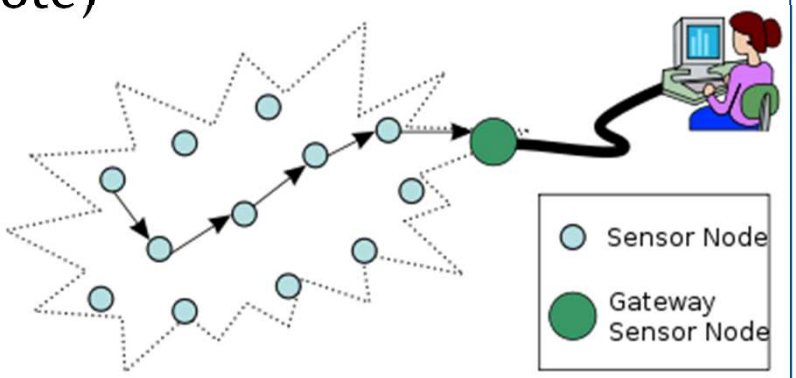
What is a Wireless Sensor Network?

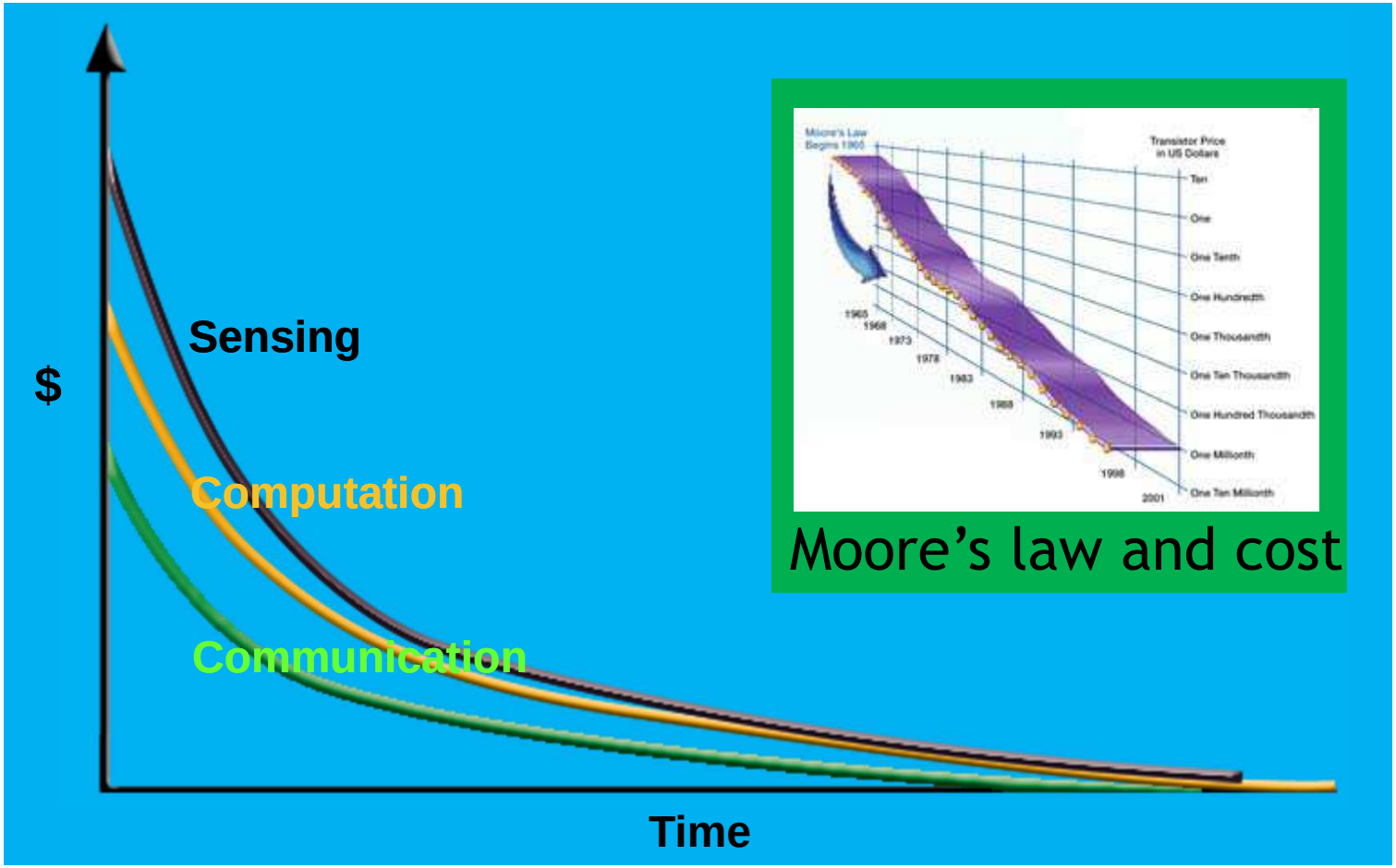
- From Wikipedia: A **Wireless Sensor Network** (WSN) consists of spatially distributed **autonomous sensors** to monitor physical or environmental conditions, such as **temperature**, **sound**, **vibration**, …, and to cooperatively pass their **data** through the network to a main location.

- Anatomy of a Sensor node (a Mote)





The seed of an idea ….



Moore's law and cost

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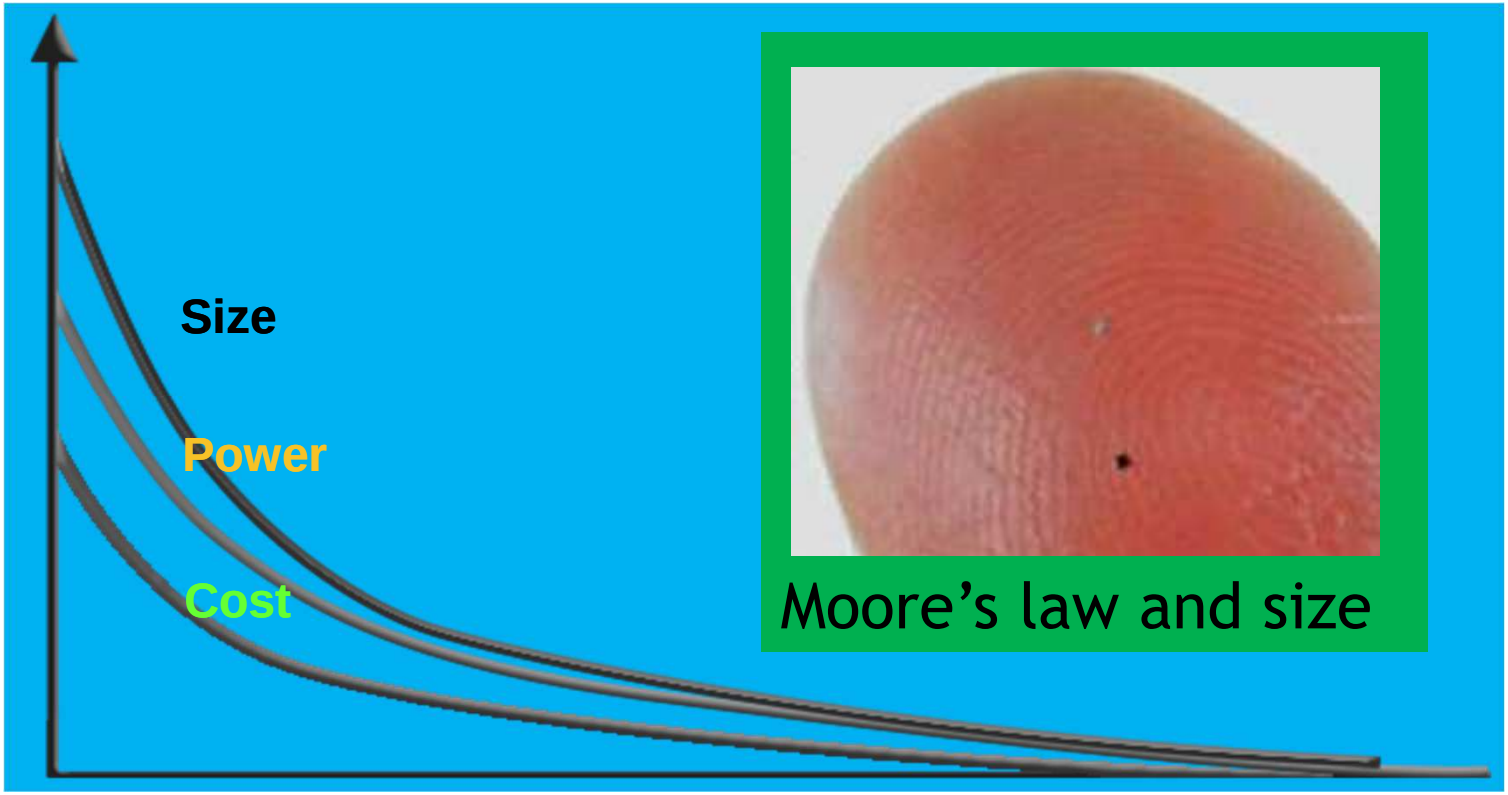
The seed of an idea ….



Wireless Sensor Technology Will Follow These Trends

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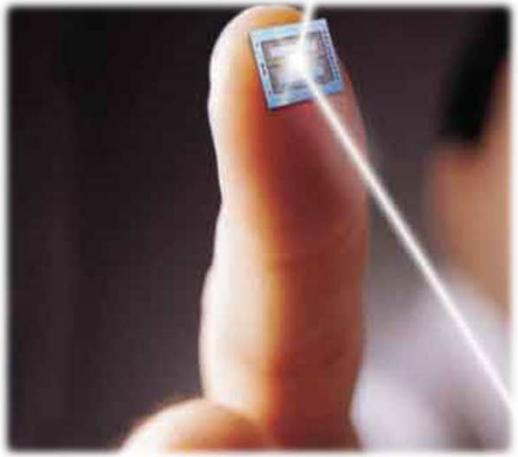
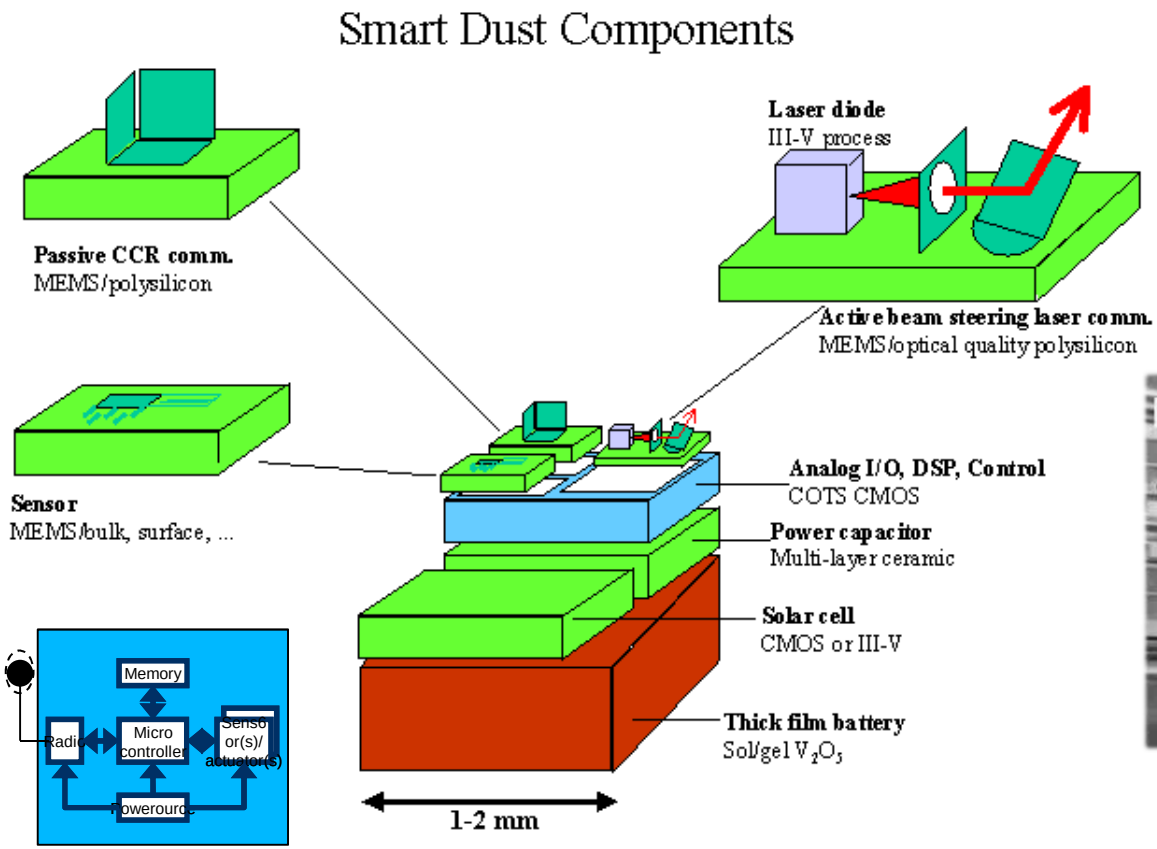
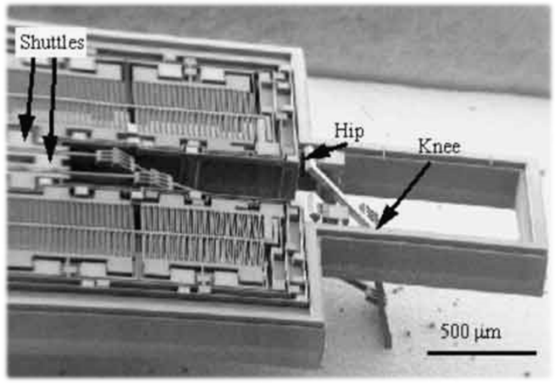
Smart Dust Idea ….

- Smart Dust Vision, 1997, UCB







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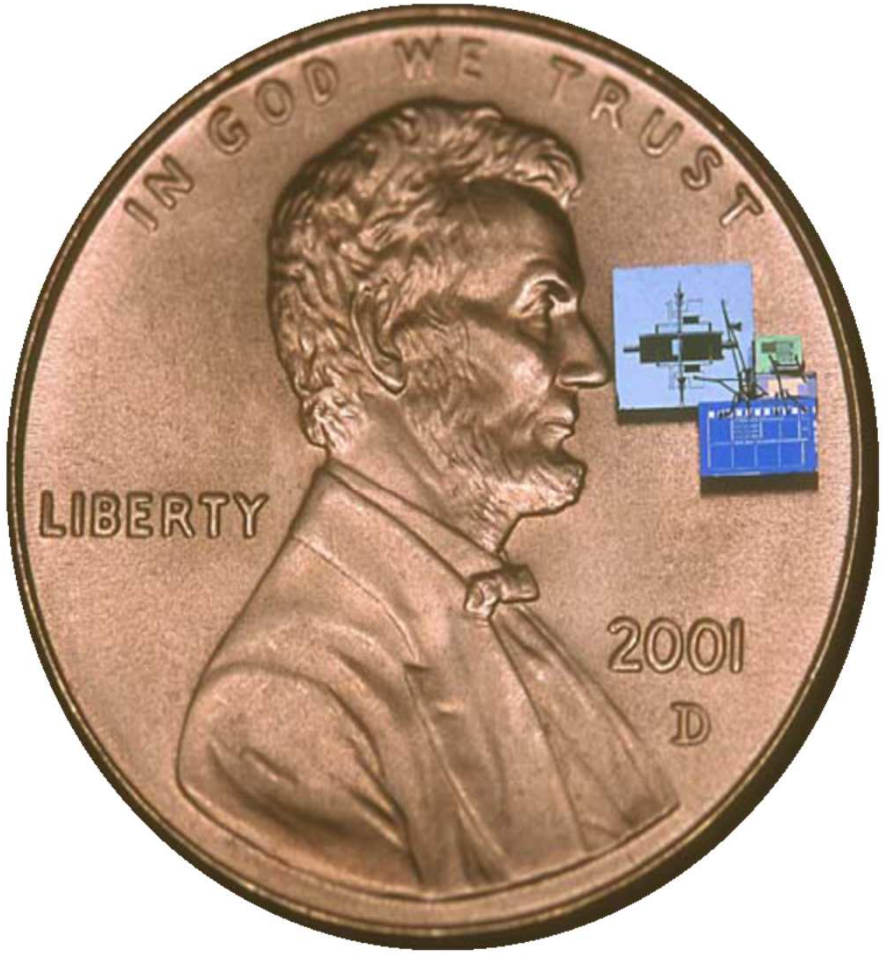
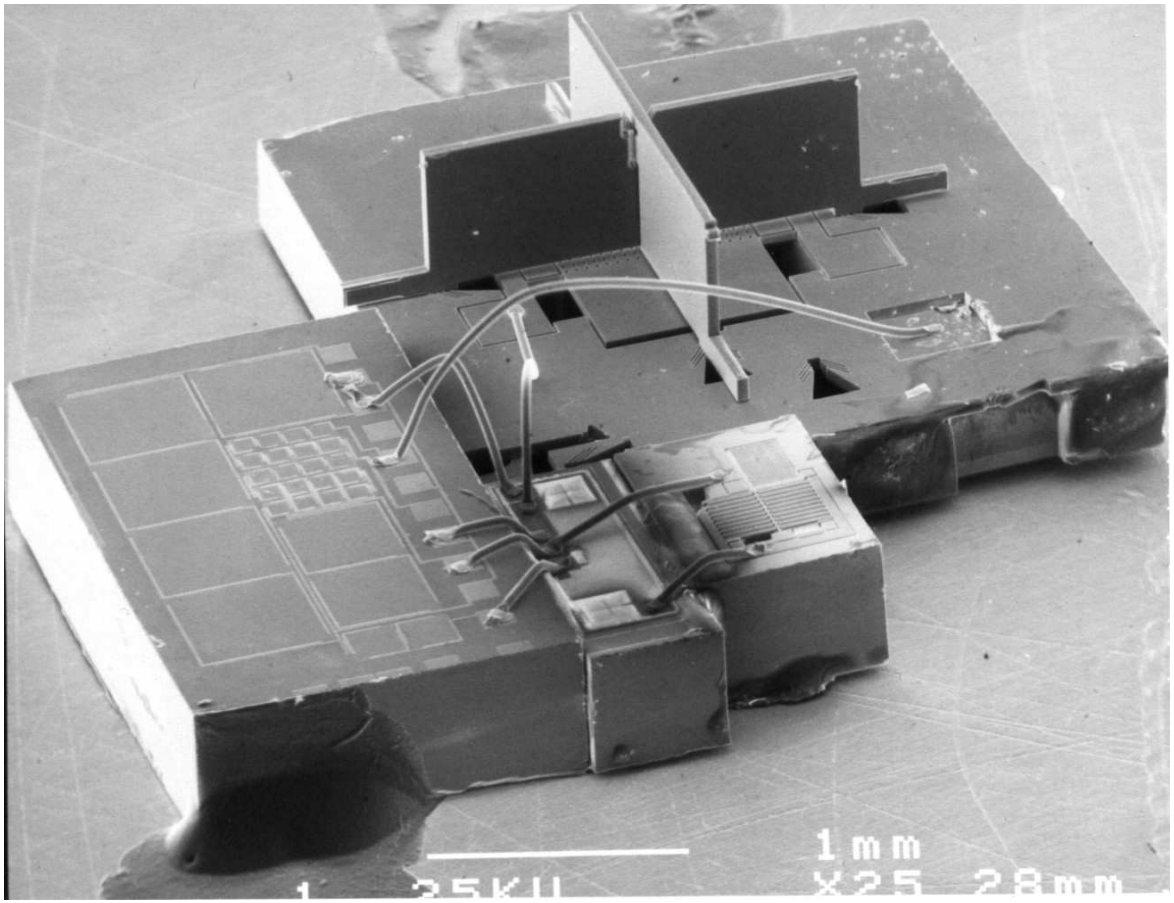
Smart Dust Integration



Smart Dust Integration



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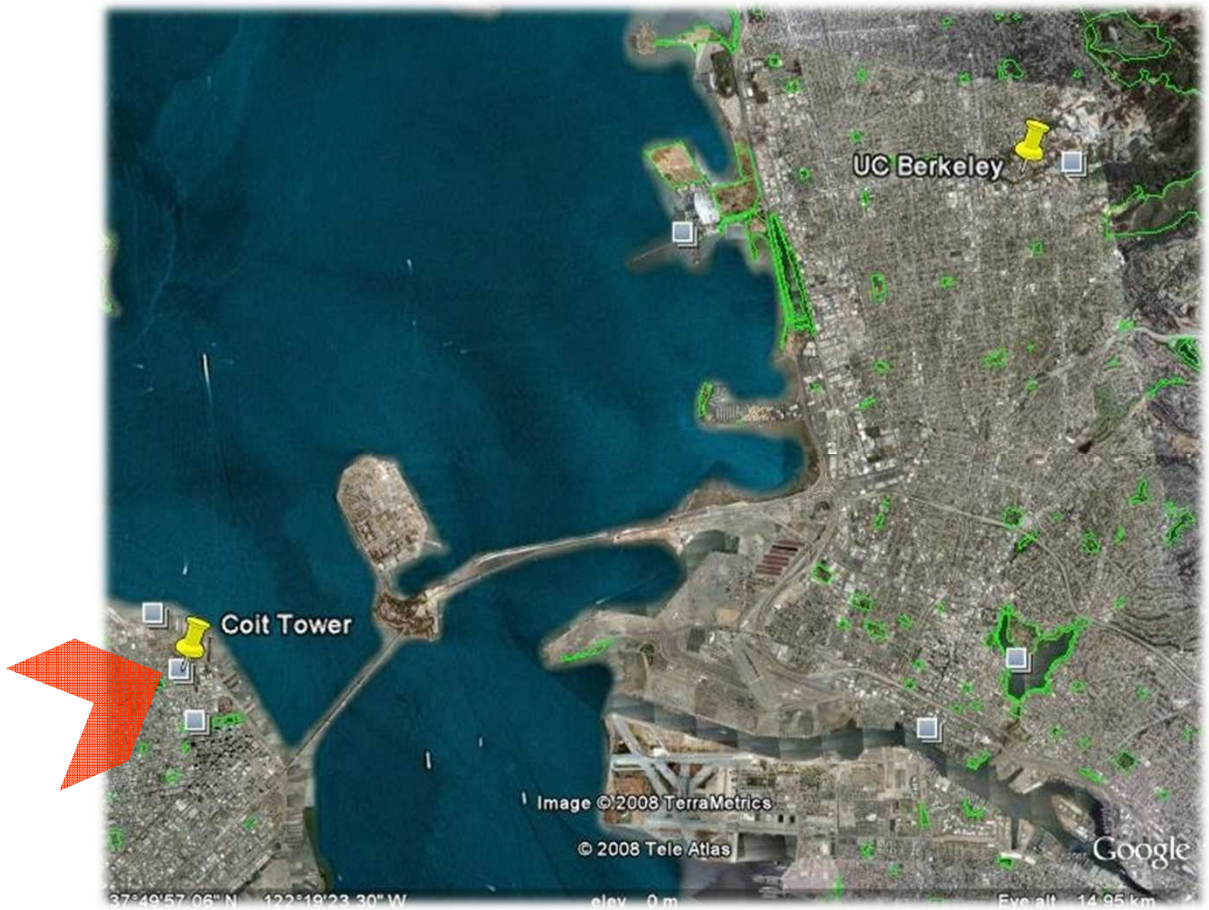
Weather data communicated wirelessly (Smart Dust, UCB – San Fransisco)



Economic (motivation)

- Forecast for WSNs
  - On World Expert survey “WSN Market Size in 2007 and Active RFID and Sensor Networks 2007-2017”:
    - Industrial applications of WSN: 4.6 billion $ by 2011
    - Smart building applications of WSN: 2.5 billion $ by 2011

- The future is bright for many jobs and start’ups in the WSN space!

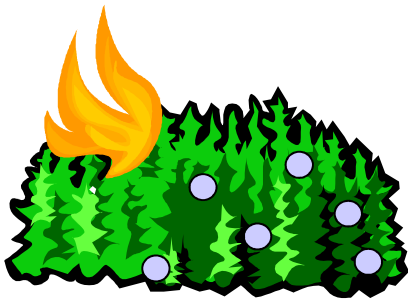
WSN applications

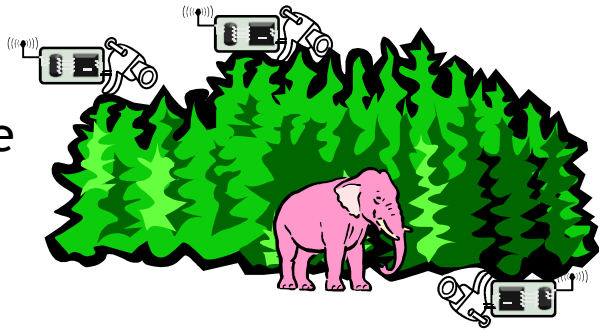
Some of the following slides are taken/inspired from supplementary material from the book *Protocols and Architectures for Wireless Sensor Networks* web-site:

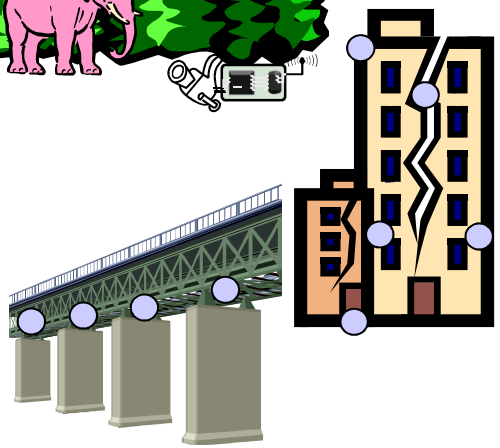
http://www.cs.uni-paderborn.de/index.php?id=1119&L=1

WSN application examples

- 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
- 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





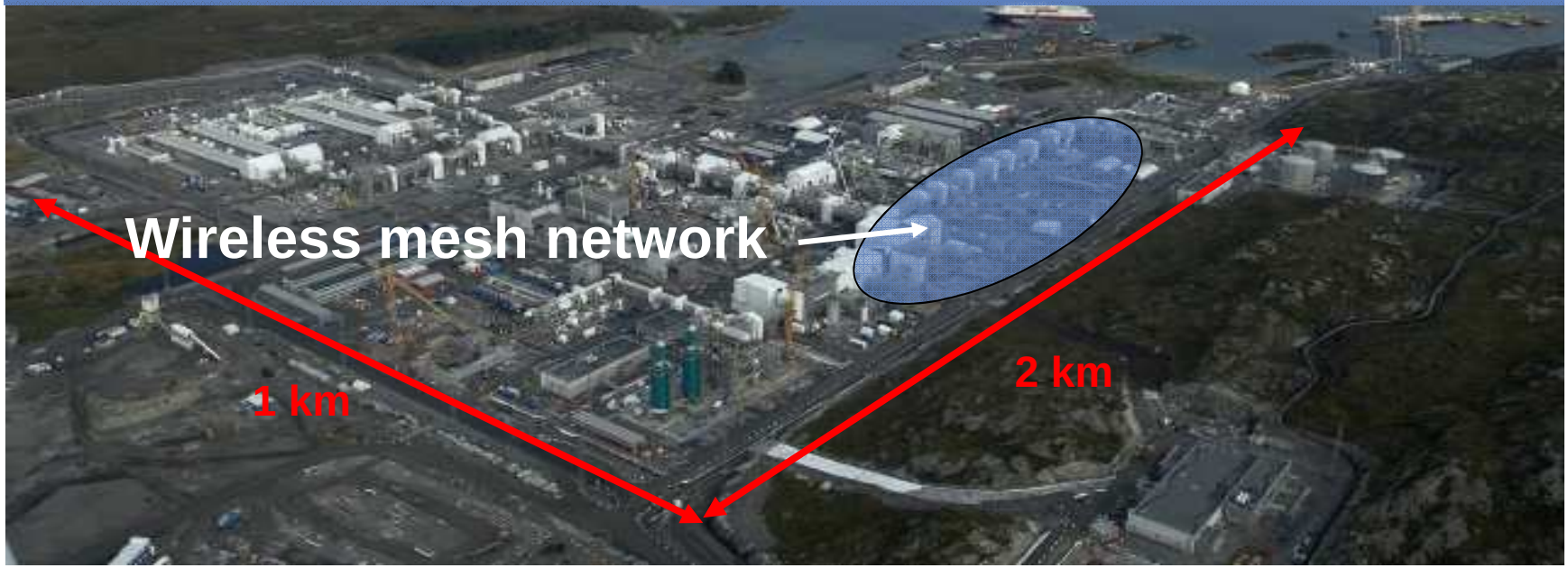


WSN application examples

- 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
- Facility management
  - Intrusion detection into industrial sites
  - Control of leakages in chemical plants, …
- … etc etc ….

Shell Oil Facility, Norway

- GE Energy's *System 1* motor condition monitoring
- 200 temperature and vibration sensors
- No line power due to hazardous location rules
- 1-2 days setup before up-and-running
    - Wiring in sensors would cause a 2 week delay in "first gas"



Source – Dust networks - www.dustnetworks.com

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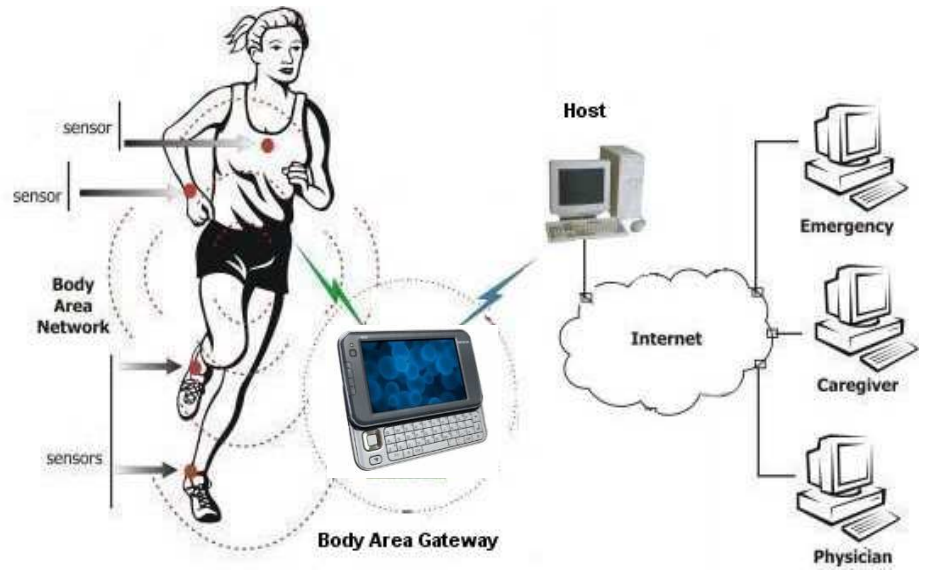
Aarhus University – research project: Virtual Power Plant for Smart Grid Ready Buildings and Customers

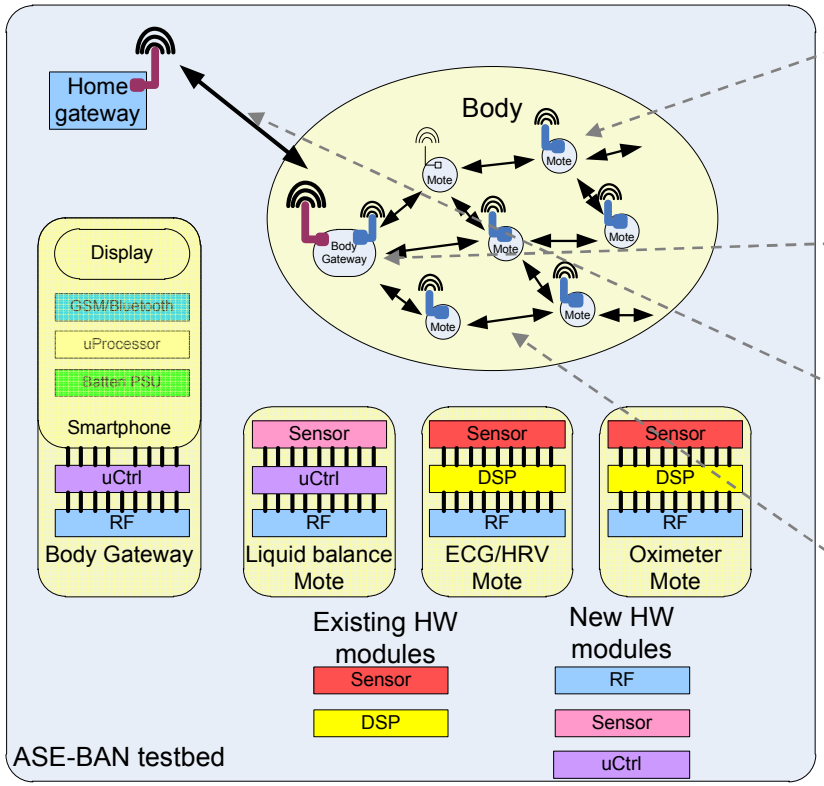
Ex: Aarhus School of Engineering Body Area Network - ASEBAN



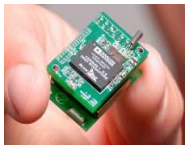
Design considerations & constraints

- Star / Mesh topology
- Data rates
  - 100 bps (temp.) -> 100 kbps
- Energy consumption
  - Low power / Energy harvesting
- Form factor, weight & comfort
- Quality of Service and reliability
- Usability
  - Plug and play
- Security and Privacy
- Etc.

ASE-BAN – test-bed



Body Motes
- ECG/HRV
- Oximeter
- Body liquid balance



Body Gateway
- Smartphone platform w.support for intra-body communication
- TinyOS

Extra-body communication
- Bluetooth
- GPRS

Intra-body communication
- 802.15.4 (2.4G)
- 6LowPAN
- TinyOS

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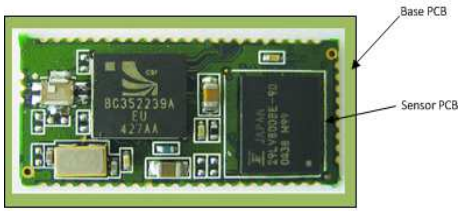
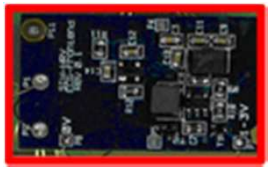
ASE-BAN: 2. generation – HW details



Liquid Bal. Sensor module
4 mm x 35mm x 18mm

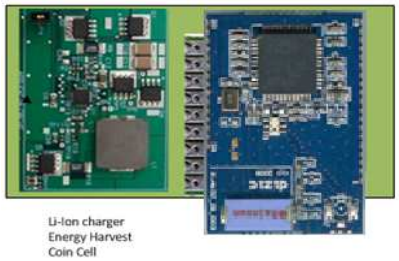
MiniUSB gateway module

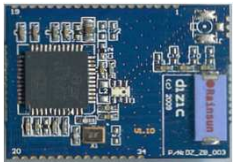


ECG Sensor module
4mm x 30mm x 18mm

ECG DSP module
4mm x 30mm x 18mm

Power module
3 mm x 20mm x 18mmx
Li-on charger
Energy Harvest
Coin cell





RF module
3 mm x 25mm x 19mm from DiZiC
- STM32W RF chip
- 802.15.4 Transceiver & MAC
- ARM Cortex M3

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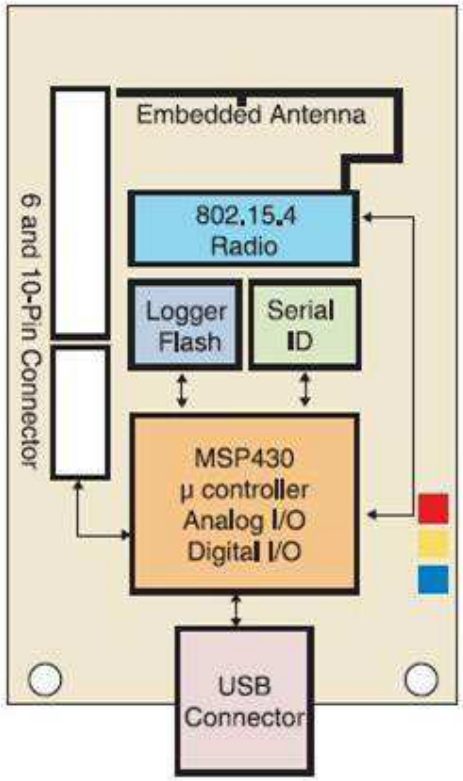
Mote to be used in Class - TelosB

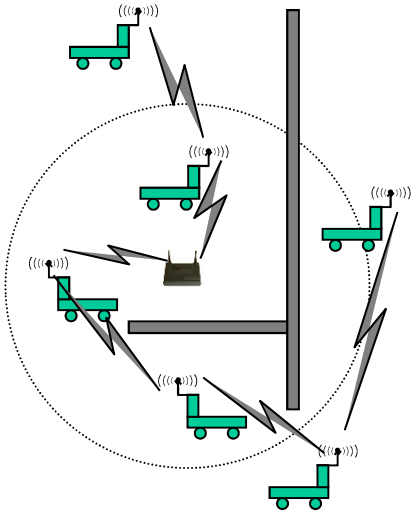


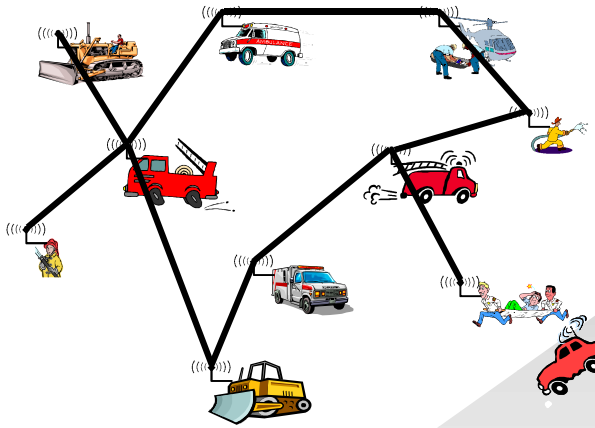
- More about this in the next lecture!

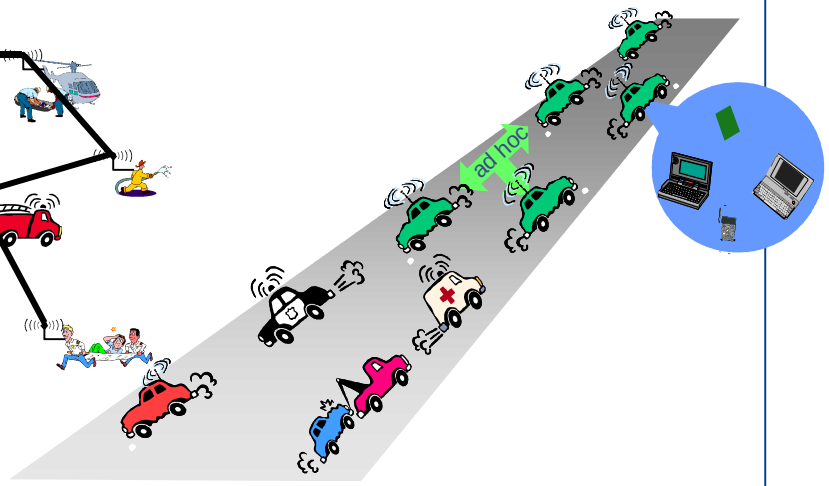
One step backwards ……

Possible appls. for infrastructure-free networks

- Factory floor automation
- Disaster recovery
- Car-to-car







- 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

Problems/challenges WSNs

- 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
  - ….

Ex: Battery-operated devices ! energy-efficient operation

- Often (not always!), participants in an WSN 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

Deployment options for WSN

- How are sensor nodes deployed in their environment?
  - 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
  - Dropped from aircraft ! ***Random deployment***
    - Usually uniform random distribution for nodes over finite area is assumed

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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

WSN Characteristics Requirements & Mechanisms

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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
  - Huge 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

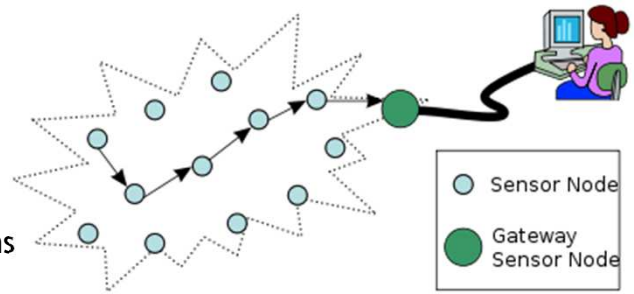
- Multi-hop wireless communication
- Energy-efficient operation
  - Both for communication and computation, sensing, actuating
- Auto-configuration
  - Manual configuration just not an option
- Collaboration & in-network processing
  - Nodes in the network collaborate towards a joint goal
  - Pre-processing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

Required mechanisms to meet requirements

- Locality
  - Do things locally (on node or among nearby neighbors) as far as possible
- Exploit tradeoffs
  - E.g., between invested energy and accuracy
- …

Summary

- WSNs: Distributed sensing, computing, transmitting/receiving devices, wirelessly networked together for communication, control, sensing and actuation purposes
- The main characteristics of a WSN:
  - Power consumption constrains for nodes using batteries or energy harvesting
  - Ability to cope with node failures
  - Mobility of nodes
  - Dynamic network topology
  - Communication failures
  - Scalability to large scale of deployment
  - Ability to withstand harsh environmental conditions
  - Easy of use
  - Unattended operation
  - …..



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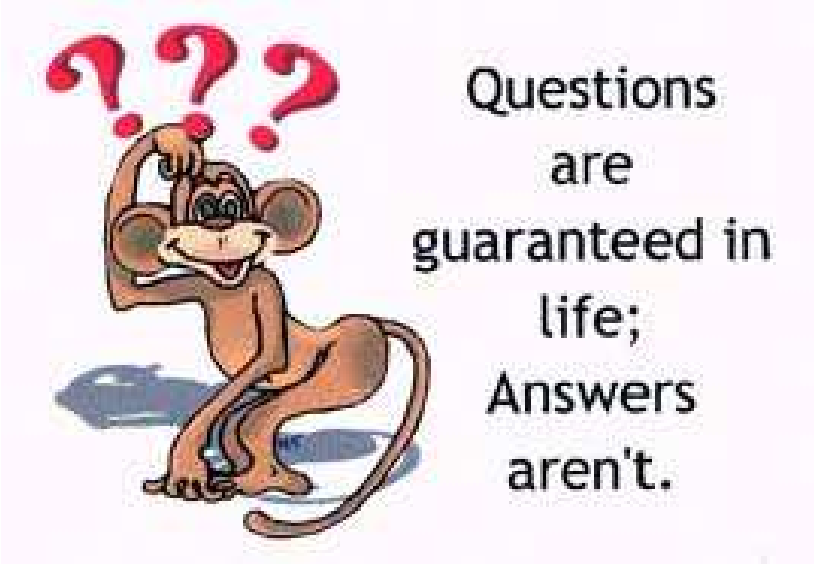
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