INTRODUCTION TO WIRELESS SENSOR NETWORKS

Marco Zennaro and Antoine Bagula

Goals of this lecture

- Give an understanding of what wireless sensor networks are good for and what their intended application areas are

- Give an idea of what their limitations and current status are

- Glimpse of Market Situation

- Future developments

Outline

- *Infrastructure for wireless?*

- (Mobile) ad hoc networks

- Wireless sensor networks
  - Mote Anatomy
  - Wireless communication

- Applications of WSN

- Potential

- Market & Future

Infrastructure-based wireless networks

□ **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

Further networks   Gateways   IP backbone

Server

Router
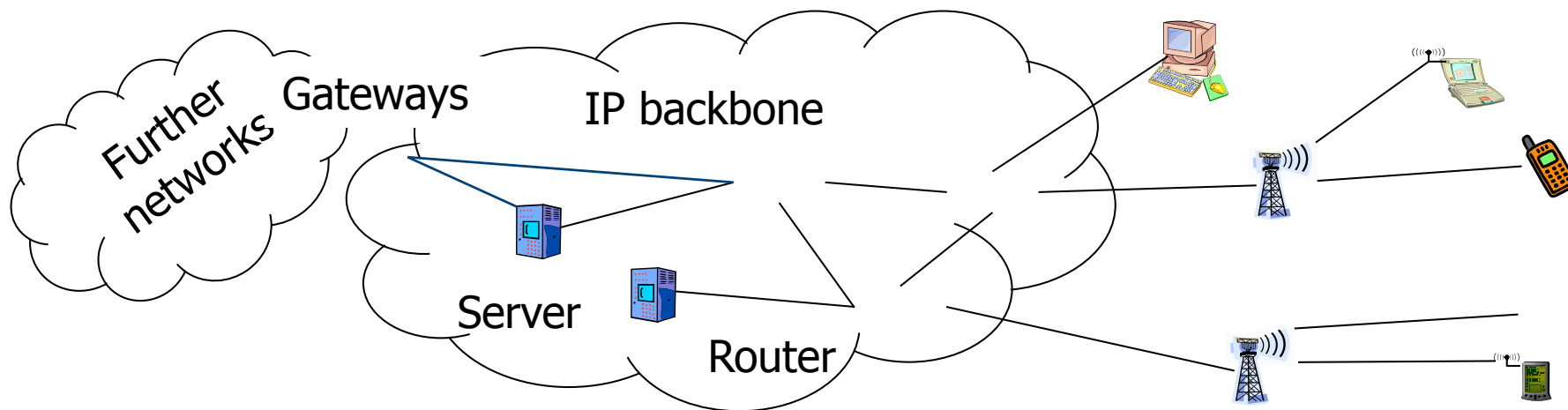
Infrastructure-based networks: limits

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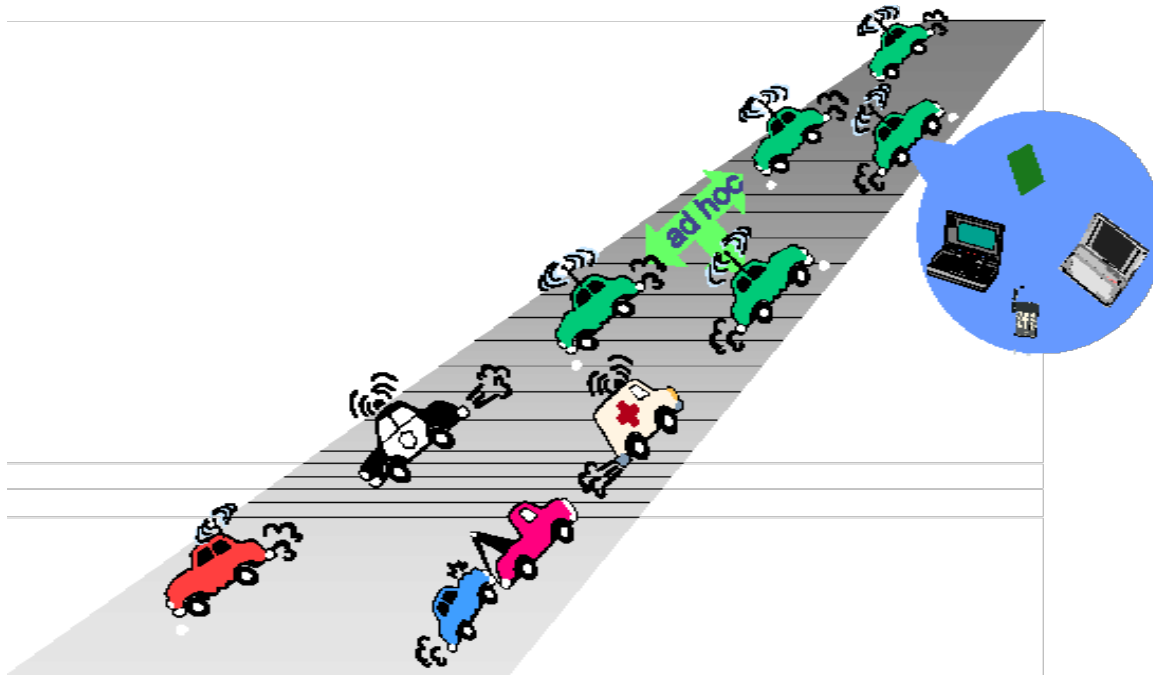 - There is no time to set it up? – E.g., in military operations

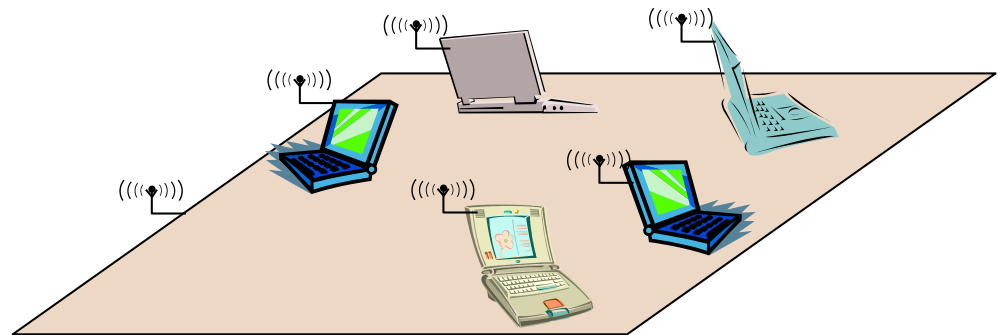# Infrastructure-free networks

- Disaster recovery
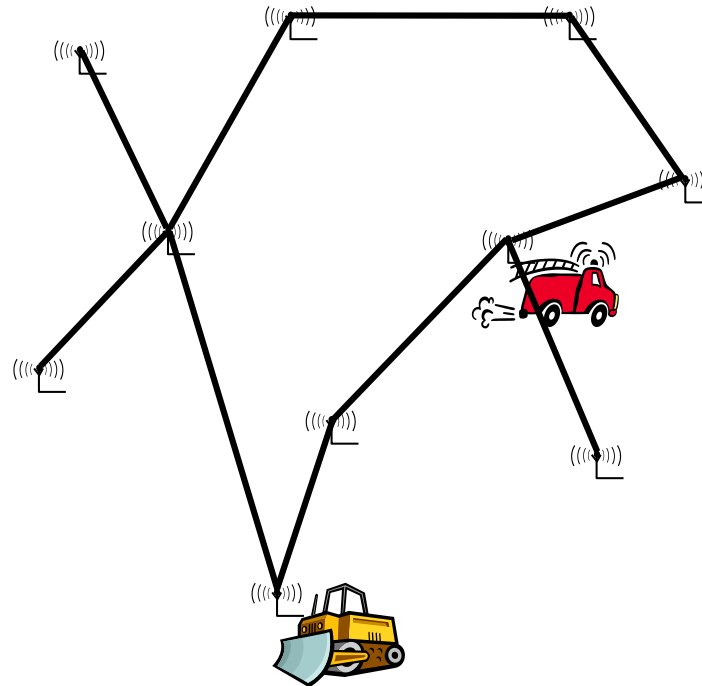
Infrastructure-free networks

- Car-to-car communication

Solution: (Wireless) ad hoc networks

- 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**

Challenges for ad hoc networks

- 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

Wireless sensor networks

☐ 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)
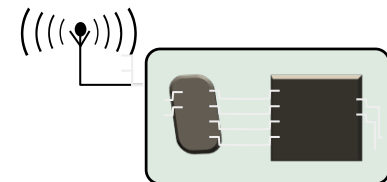
Wireless sensor networks

- A Wireless Sensor Network is a self-configuring network of small sensor nodes communicating among themselves using radio signals, and deployed in quantity to sense, monitor and understand the physical world.

- Wireless Sensor nodes are called **motes**.
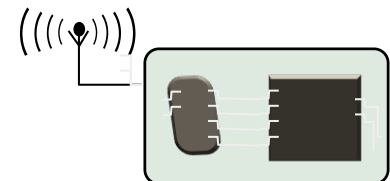
Wireless sensor networks

- WSN provide a bridge between the real physical and virtual worlds.

- Allow the ability to observe the previously unobservable at a fine resolution over large spatio-temporal scales.

- Have a wide range of potential applications to industry, science, transportation, civil infrastructure, and security.

Wireless sensor networks

log (people per computer)

0

1960   1970   1980   1990   2000   2010   [Culler:2004]
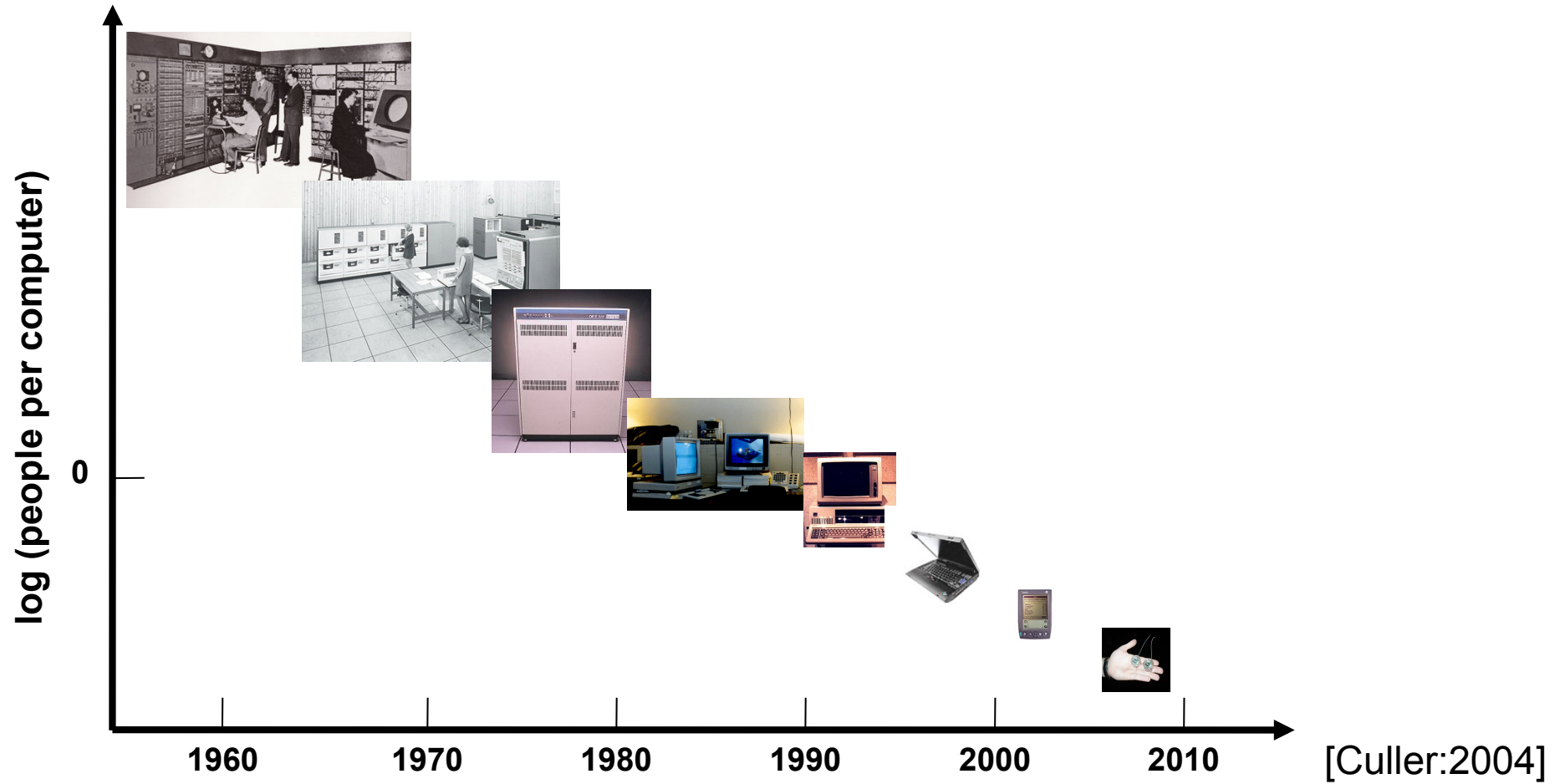
Wireless sensor networks
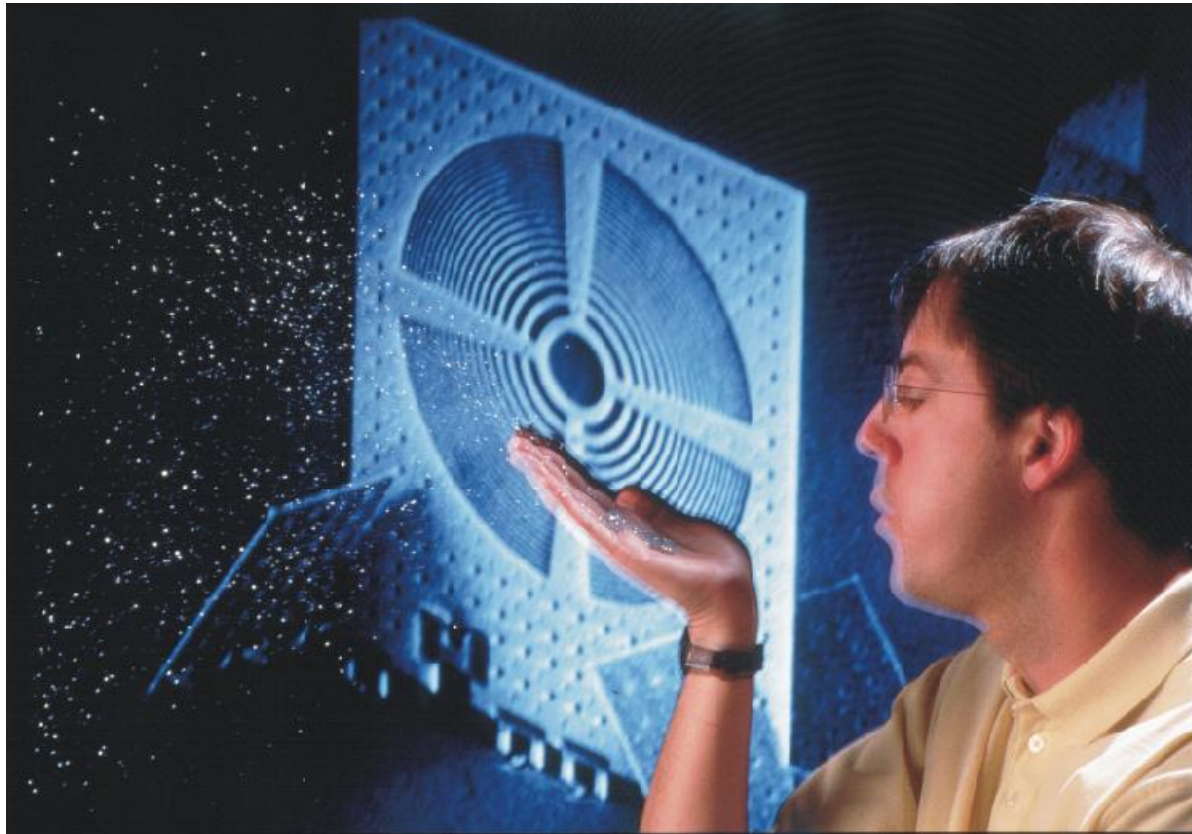
Next Century
Challenges: Mobile
Networking for
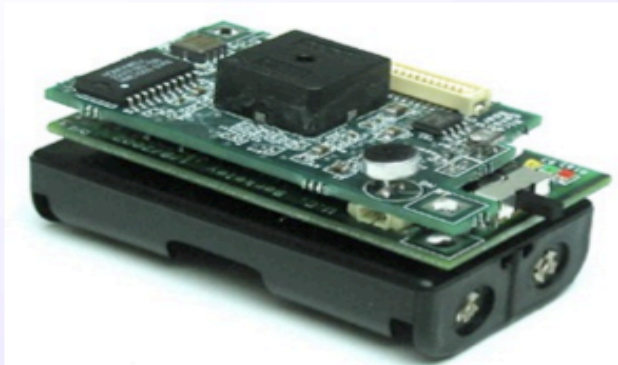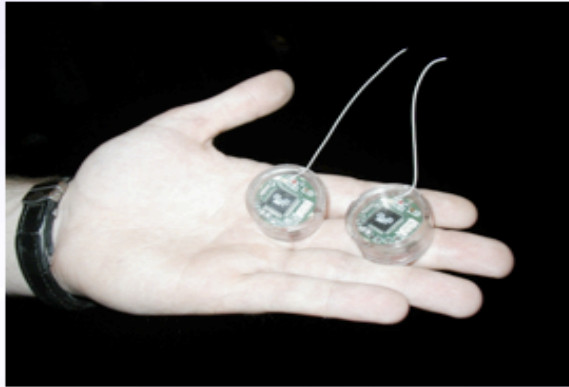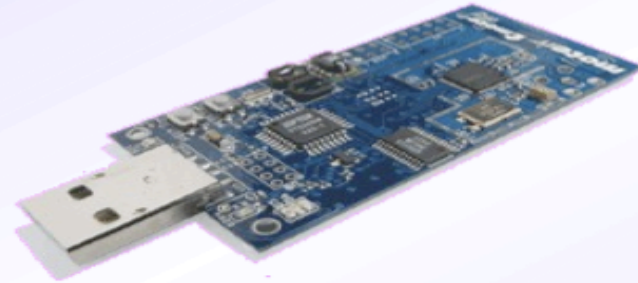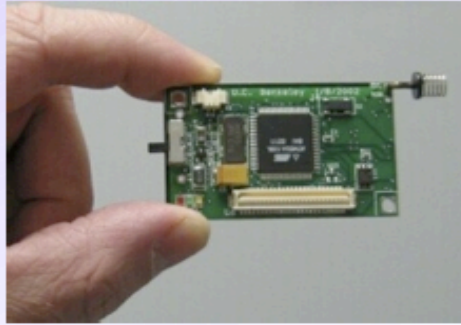"**Smart Dust**"

J. M. Kahn,
R. H. Katz,
K. S. J. Pister

(MobiCom 1999)

Mote Anatomy

- Processor in various modes (sleep, idle, active)

- Power source (AA or Coin batteries, Solar Panels)

- Memory used for the program code and for in-memory buffering

- Radio used for transmitting the acquired data to some storage site

- Sensors for temperature, humidity, light, etc

Mote Anatomy

Wireless communication

- The two wireless standards used by WNS are 802.15.4 and Zigbee

- They are low-power protocols

- Performance is an issue

- Max distance is around 100 m

Wireless communication: 802.15.4

- Channels:
   - 868.0 - 868.6MHz   -> 1 channel   (Europe)
    - 902.0-928.0MHz   -> 10 channels (EEUU)
    - 2.40-2.48GHz   -> 16 channels (Worldwide)

- Bit Rates:
    - 868.0 - 868.6MHz   -> 20/100/250 Kb/s
    - 902.0-928.0MHz   -> 40/250 Kb/s
   - 2.40-2.48GHz   -> 250 Kb/s

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
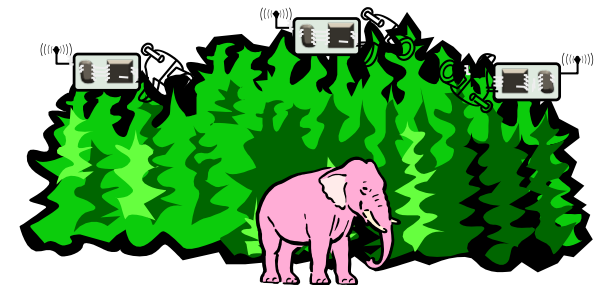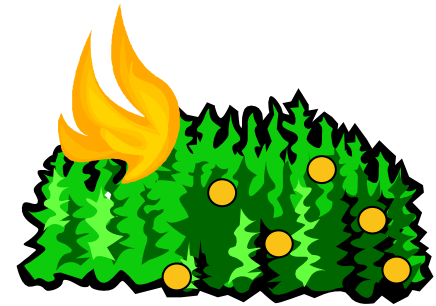
WSN application examples

- 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
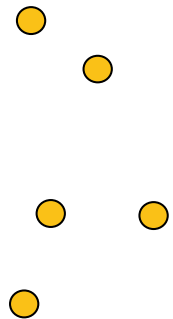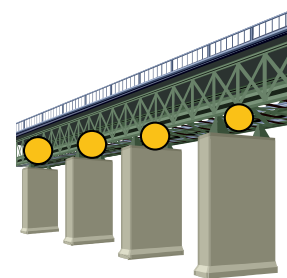
WSN application examples

- 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 examples

[Princeton, 2004]

WSN application examples

- ZebraNet: an application to track zebras on the field
- The objective of the application is to gather dynamic data about zebra positions in order to understand their mobility patterns.
- What are the motivations for the zebras to move? water? food? weather?
- How do they interact?
- The sensors are deployed in collars that are carried by the animals.
- The users are the biologists.

Outline

- Infrastructure for wireless?
- (Mobile) ad hoc networks
- **Wireless sensor networks**
    - Mote Anatomy
    - Wireless communication
- Applications of WSN
- *Potential*
- Market & Future

Potential

- US National Research Council report ("Embedded Everywhere"): the use of wireless sensor networks (WSN) could well dwarf previous milestones in the information revolution.

- MIT's Technology Review in February 2003 predicted: WSN will be one of the most important technologies in the near future.

- Nature, in the "2020 computing: Everything, everywhere" report, said that WSN are going to be one of the most interesting technologies.
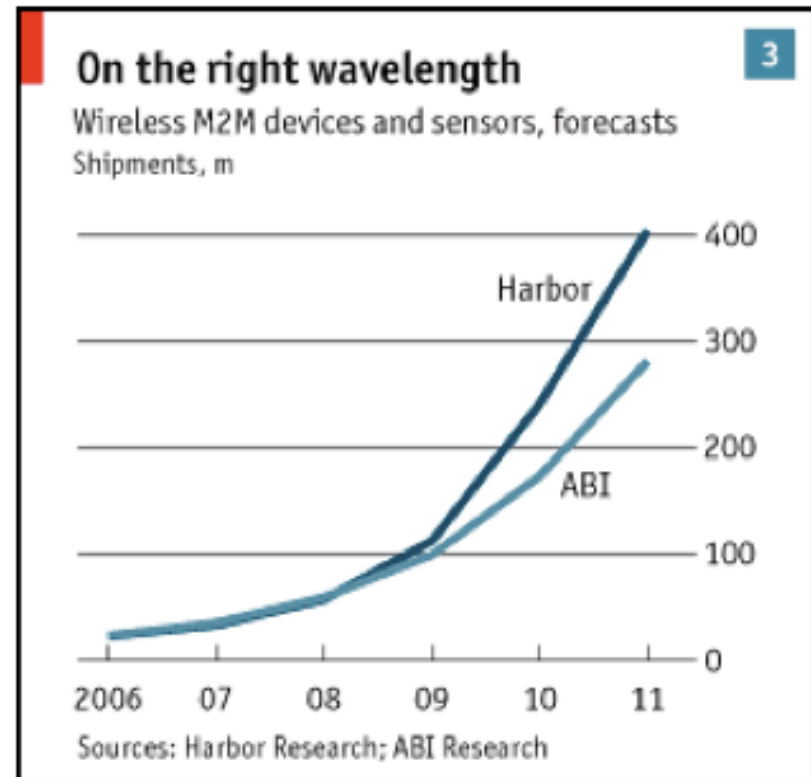
Potential

Mote maker: David Culler's "motes" monitor the environment and send reports wirelessly. (Photograph by Angela Wyant)
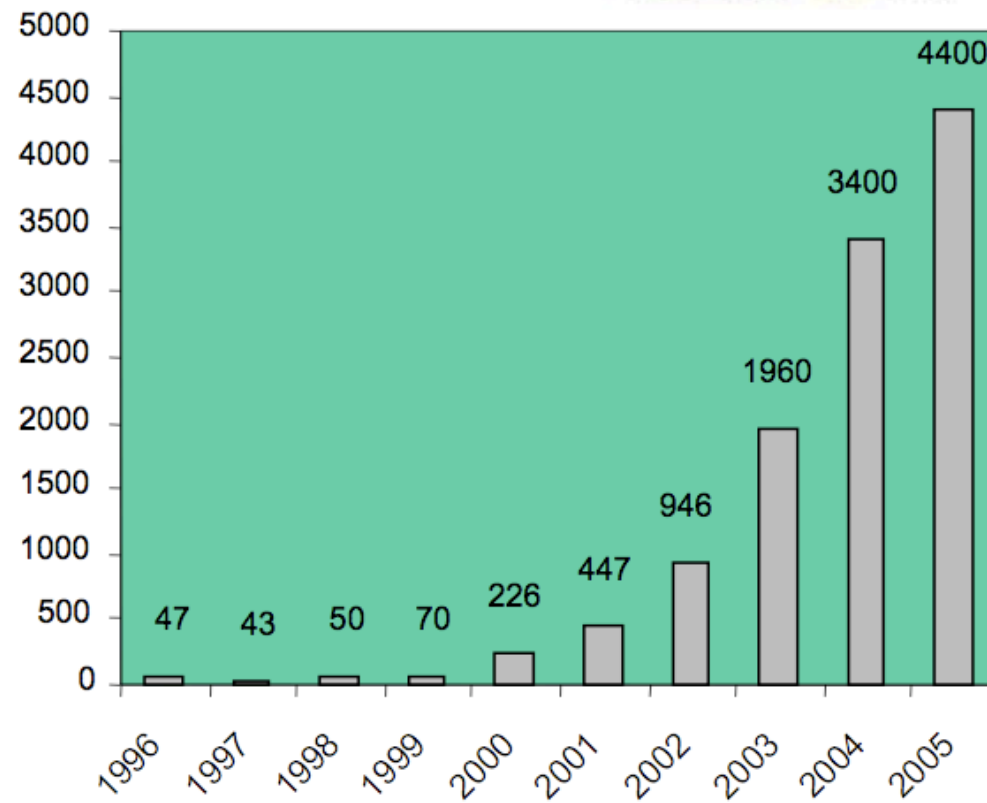
Potential

- The Economist, in April 2007, had an issue called "When everything connects".

Potential

Market

- There are a couple of companies producing WSN: Sun, Sentilla and Libelium to name a few.

- The products they sell are quite different, but still require an expert to setup and use.

- Sun and Sentilla products are based on Java.

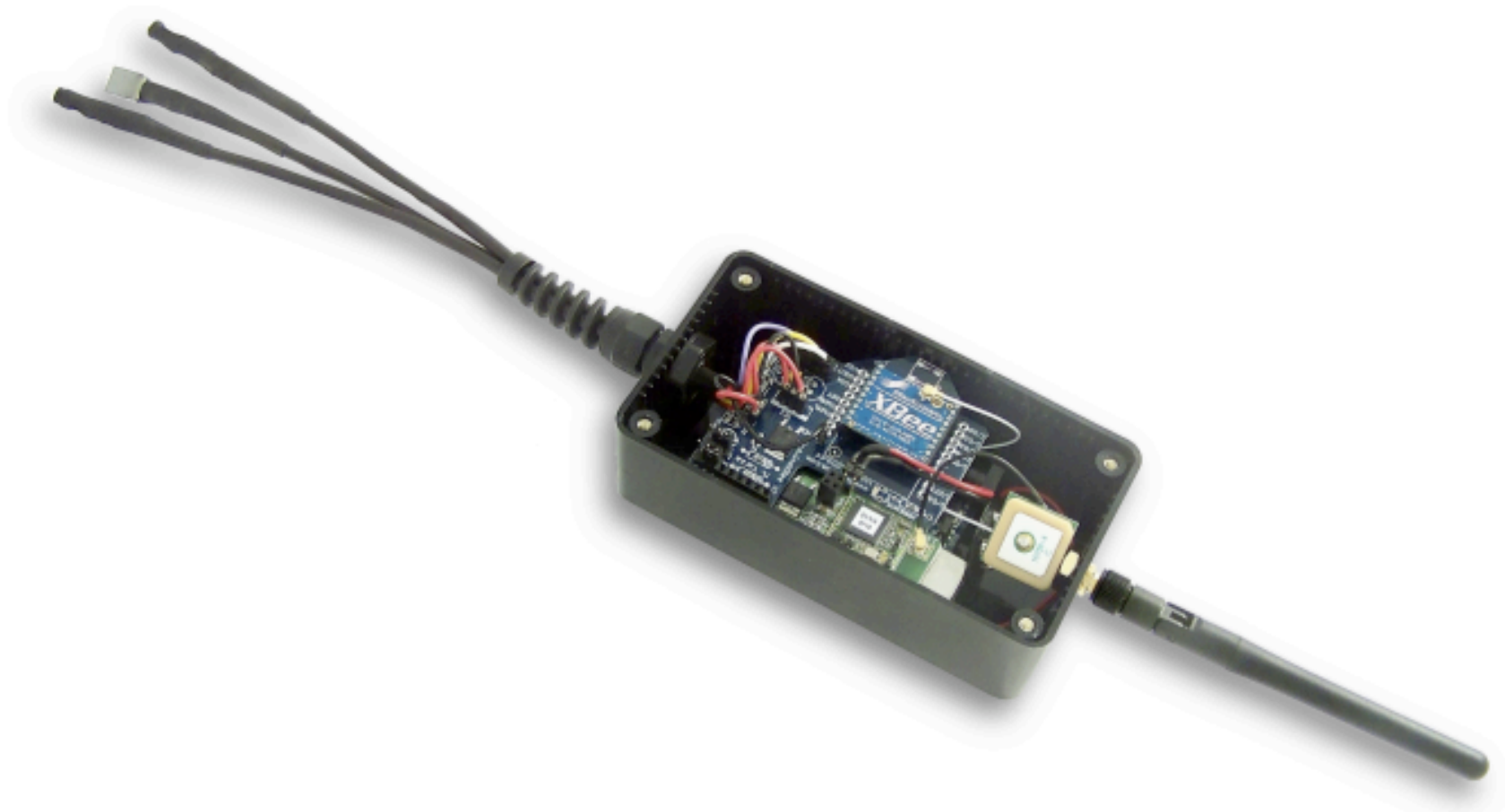- Libelium is based on Arduino and Open Source software.

Market: Libelium

- Open Source Project

- Based on Arduino board + Zigbee module

- Their WSN is called Squidbee

- Price is low: 100 euros per Squidbee
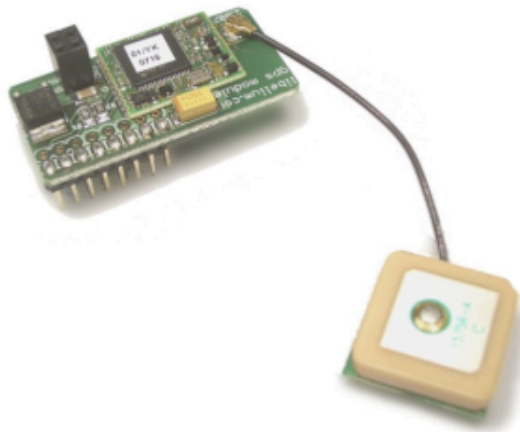
- Very supportive community

- www.libelium.com

Market: Libelium
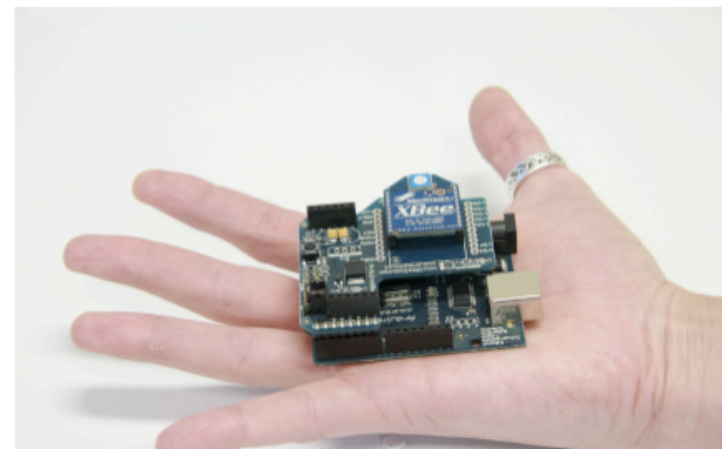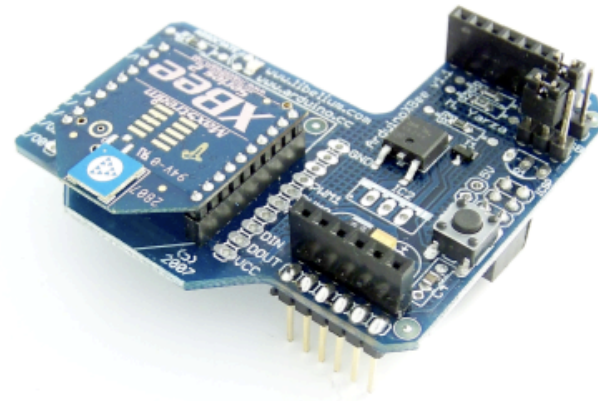
Market: Libelium

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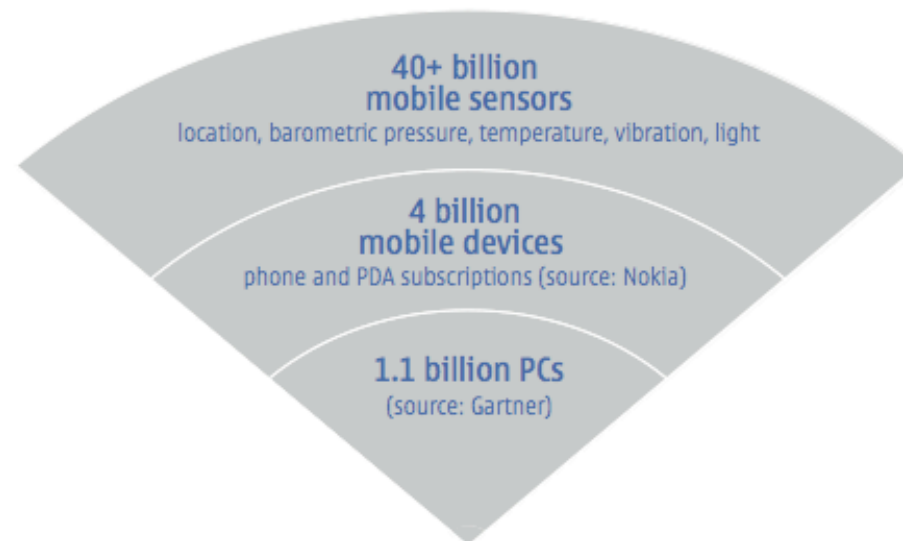
Market: Libelium

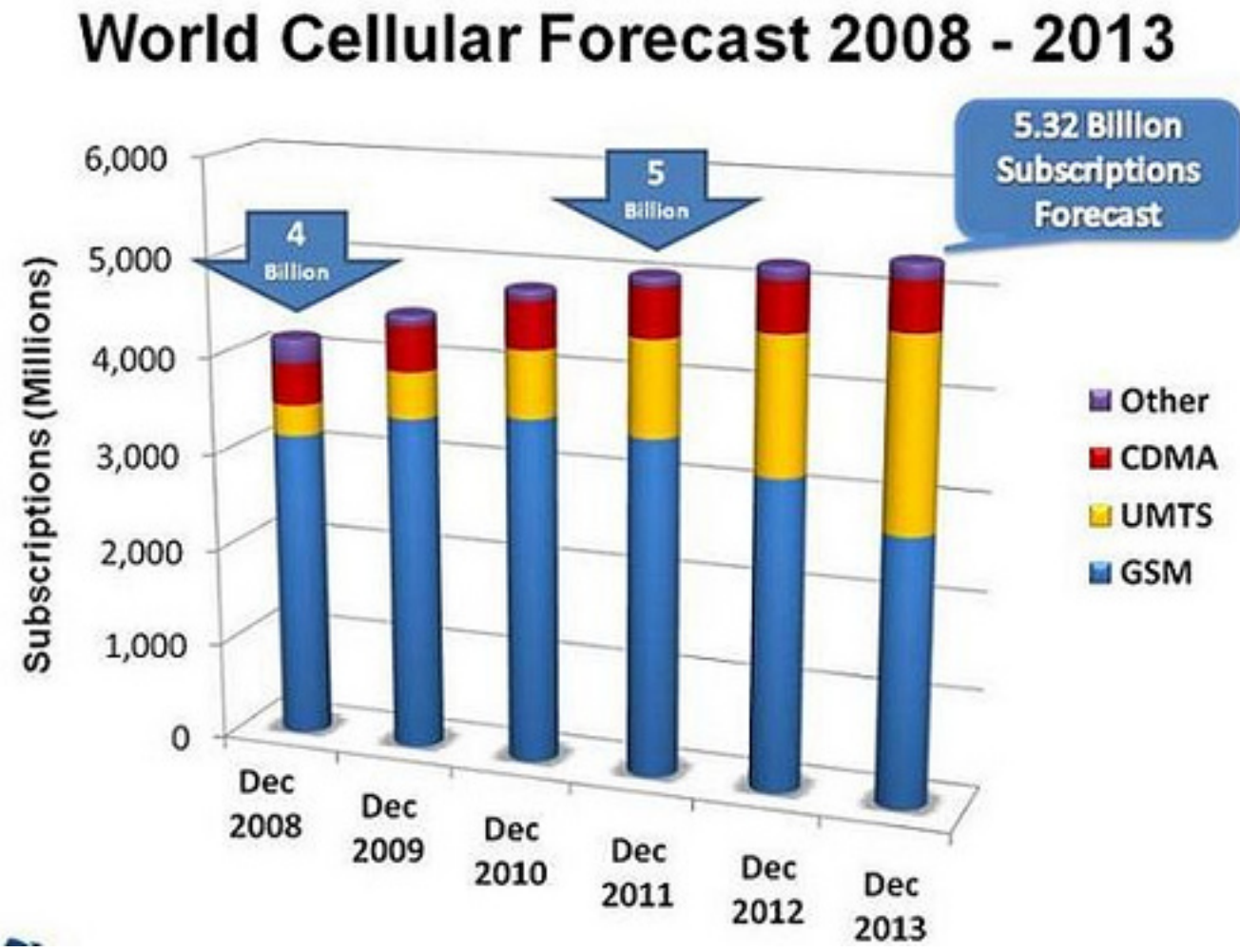# Future

Future: mobiles as sensors?

Sensing and sensors everywhere

As mobile device subscriptions pass the four billion mark, we're looking at the world's most distributed and pervasive sensing instrument. Thanks to an increasing number of built-in sensors—ambient light, orientation, acoustical, video, velocity, GPS—each device can capture, classify, and transmit many types of data with exceptional granularity. The perfect platform for sensing the world is already in our hands.

2009 Projection

40+ billion mobile sensors
location, barometric pressure, temperature, vibration, light

4 billion mobile devices
phone and PDA subscriptions (source: Nokia)

1.1 billion PCs
(source: Gartner)

Future: mobiles as sensors?

Future: mobiles as sensors?

Conclusion

- WSN are here to stay!

- It's an interesting, complex, new technology

- Lots of research still to be done

- Applications are what is needed!

Thanks

Marco Zennaro

mzennaro@ictp.it

www.wsnblog.com