INTRODUCTION TO WIRELESS SENSOR NETWORKS

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In theory, there is no difference between theory and practice.
But, in practice, there is.

Jan L. A. van de Snepscheut (1953 – 1994) was a computer scientist and educator.
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
- Future developments
Outline

- Wireless sensor networks
  - Mote Anatomy
  - Wireless communication
- Potential VS Reality
- Future
Wireless sensor networks

- Alternative concept in MANETs:

  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)*
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

[Diagram showing the history of computers from 1960 to 2010, with the vertical axis representing log (people per computer)].

[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

- Memory
- Communication device
- Controller
- Power supply
- Sensor(s)/ actuator(s)
Mote Anatomy
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
This standard defines a communication layer at level 2 in the OSI (Open System Interconnection) model. Its main purpose is to let the communication between two devices. It was created by the Institute of Electrical and Electronics Engineers (IEEE), entity which main task is to set standards so that technological developments can count with a common platform of rules to be set over.
This standard defines a communication layer at level 3 and uppers in the OSI model. Its main purpose is to create a network topology (hierarchy) to let a number of devices communicate among them and to set extra communication features such as authentication, encryption, association and in the upper layer application services. It was created by a set of companies which form the ZigBee Alliance.
As mentioned before this protocol lies over the level 2 of the OSI. This layer is called the Data Link. Here the digital information units (bits) are managed and organized to become electromagnetic impulses (waves) on the lower level, the physical one.
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
Why is it low power:

- It is ready to work with low-duty cycles. It means that the transceiver can be sleeping most of the time (up to 99% on average) while the receiving and sending tasks can be set to take just a small part of the devices' energy.
- This percentage depends on the kind of communication model used.
Wireless communication: Zigbee

- ZigBee offers basically four kinds of different services:
  - **Encryption** services (application and network keys implement extra 128b AES encryption)
  - Association and **authentication** (only valid nodes can join to the network).
  - **Routing** protocol: AODV, a reactive ad hoc protocol has been implemented to perform the data routing and forwarding process to any node in the network.
  - **Application** Services: An abstract concept called "cluster" is introduced. Each node belongs to a predefined cluster and can take a predefined number of actions. Example: the "house light system cluster" can perform two actions: "turn the lights on", and "turn the lights off".
Wireless sensor networks
- Mote Anatomy
- Wireless communication

Potential VS Reality

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)
The Economist, in April 2007, had an issue called “When everything connects”.

![Graph showing the growth of wireless M2M devices and sensors forecasts for ABI and Harbor from 2006 to 2011. Sources: Harbor Research; ABI Research.](image)
Potential

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Potential

Talking Shop

The concept of machines talking to machines was once the domain of science fiction fantasy. No more. Firms need to grapple with how it will transform business models.

By NICK CLAYTON

In 2007, there were 500 million devices connected to the Internet. By 2020, that could reach 50 billion, according to networking giant Cisco. This is the so-called “Internet of things”. A web where machines dominate. Strictly speaking, the Internet of things is a subset of a much bigger phenomenon: A machine-to-machine (M2M) net of sensors, actuators and processors.

M2M communications sees a device, such as a sensor or meter, to capture information – like temperatures, inventory levels or location status. This is then relayed through a network to an application, which translates the captured event into meaningful information. For example: a security breach, or when items need to be restocked or an accident has occurred.

CupGemini estimates that the world M2M market will be worth €27.4 billion ($39.3 billion) by 2013. According to Vodafone, just the wireless traffic alone will be worth €8.9 billion. Many of these nets of sensors and processors...
Potential

The Growth of Connected Devices

- Consumer Telematics
- Commercial Telematics
- Smart Metering (Utilities)
- Consumer Electronics
- Retail
- Cellular Connected Buildings
- Remote Health Monitoring
- Total

Source: Juniper Research
Reality

“I have Motes.”
Aka I write simulation papers.

“I have downloaded the TOS installer.”

“I checked out a demo example.”

“I changed a line of code.”

“I use CVS and contribute.”
Reality

As of July 2007

Years to mainstream adoption:
- ○ less than 2 years
- ● 2 to 5 years
- ● 5 to 10 years
- ▲ more than 10 years
- ◊ obsolete before plateau

Source: Gartner (July 2007)
Reality

Performance is Poor – Causes Are Not Understood

Sensornets Are Hard

- Sensor networks often fail/operate poorly
  - Great Duck Island network: median yield 58% [SenSys 2004]
  - Redwood network: median yield 40% [SenSys 2005]
  - Volcano network: median yield 68% [OSDI 2006]
- Survey of causes
  - Protocol conflicts/interference
  - Collisions and congestion induced loss
  - Neighbor management (with layer 2 scheduling, e.g. TMAC)
  - Don’t know!
- Low-power, limited resources make complete logging prohibitively expensive...
module BlinkM {
    provides {
        interface StdControl;
    }
    uses {
        interface Timer;
        interface Leds;
    }
}

implementation {
    command result_t StdControl.init() {
        call Leds.init();
        return SUCCESS;
    }

    command result_t StdControl.start() {
        // Start a repeating timer that fires every 1000ms
        return call Timer.start(TIMER_REPEAT, 1000);
    }

    command result_t StdControl.stop() {
        return call Timer.stop();
    }

    event result_t Timer.fired() {
        call Leds.redToggle();
        return SUCCESS;
    }
}
Outline

- Infrastructure for wireless?
- (Mobile) ad hoc networks
- **Wireless sensor networks**
  - Mote Anatomy
  - Wireless communication
- Potential VS Reality
- **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?

<table>
<thead>
<tr>
<th>2002</th>
<th>2008</th>
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<tbody>
<tr>
<td>Traditional sensor networks</td>
<td>Participatory sensing</td>
</tr>
<tr>
<td>Specially designed and deployed hardware</td>
<td>Leveraging available devices</td>
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<tr>
<td>Fully automatic and standalone systems</td>
<td>Humans in the loop</td>
</tr>
<tr>
<td>Thousands of small devices</td>
<td>Systems of heterogeneous devices</td>
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<tr>
<td>Fixed, static devices</td>
<td>Total mobility</td>
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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!
Credits

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Thanks

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