Wireless Sensor Networks

3rd Lecture

31.10.2006

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

Christian Schindelhauer
schindel@informatik.uni-freiburg.de

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)

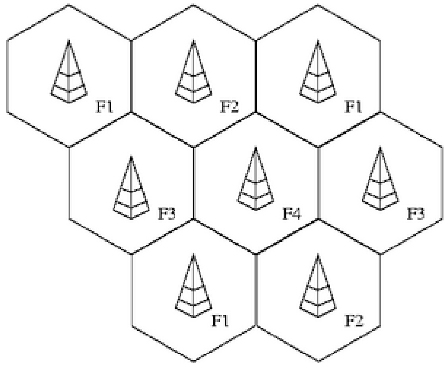
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

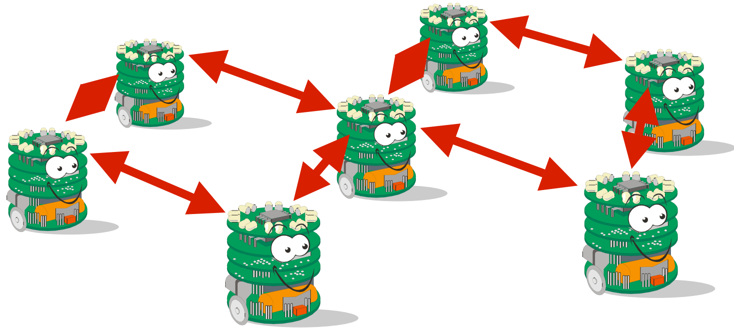
Enabling Technologies for WSN

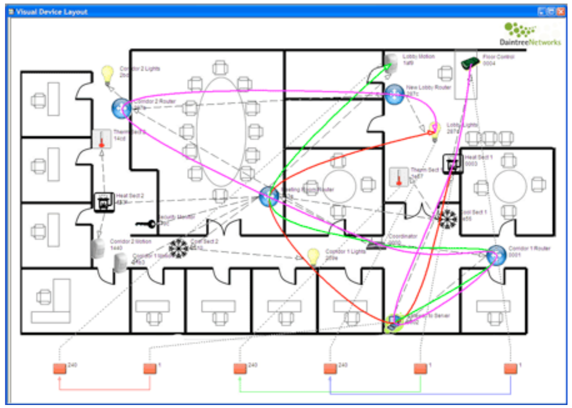
- **Cost reduction**
  - For wireless communication, simple microcontroller, sensing, batteries
- **Miniaturization**
  - Some applications demand small size
  - "Smart dust" as vision
- **Energy harvesting**
  - Recharge batteries from ambient energy (light, vibration, …)

Types of Radio Networks

- **Cellular Networks**
  - base stations distributed over the field
  - each base station covers a cell
  - used for mobile phones
  - WLAN can be seen as a special case
- **Mobile Ad Hoc Networks**
  - self-configuring network of mobile nodes
  - node serve as client and router
  - no infrastructure necessary
- **Sensor Networks**
  - network of sensor devices with controller and radio transceivers
  - base station with more resources



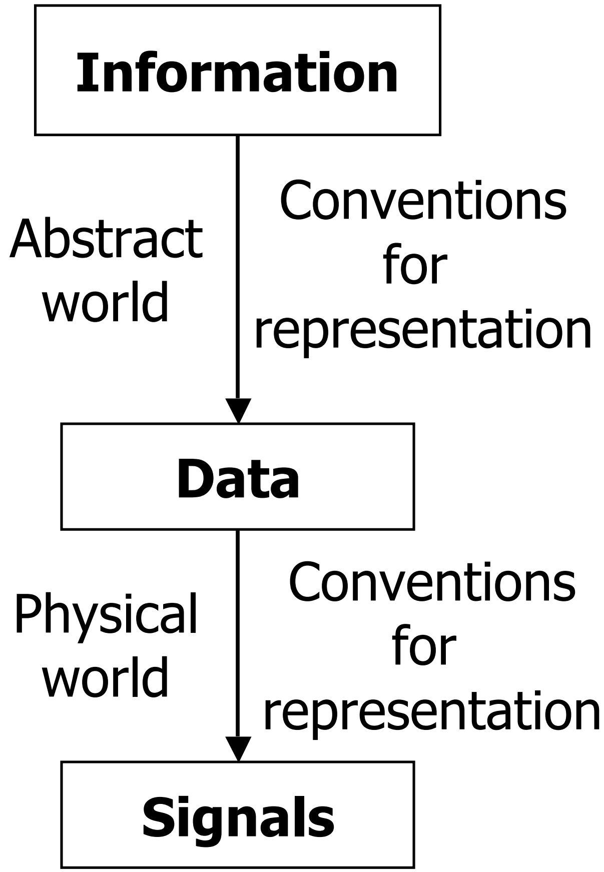




Computer Networking Basics

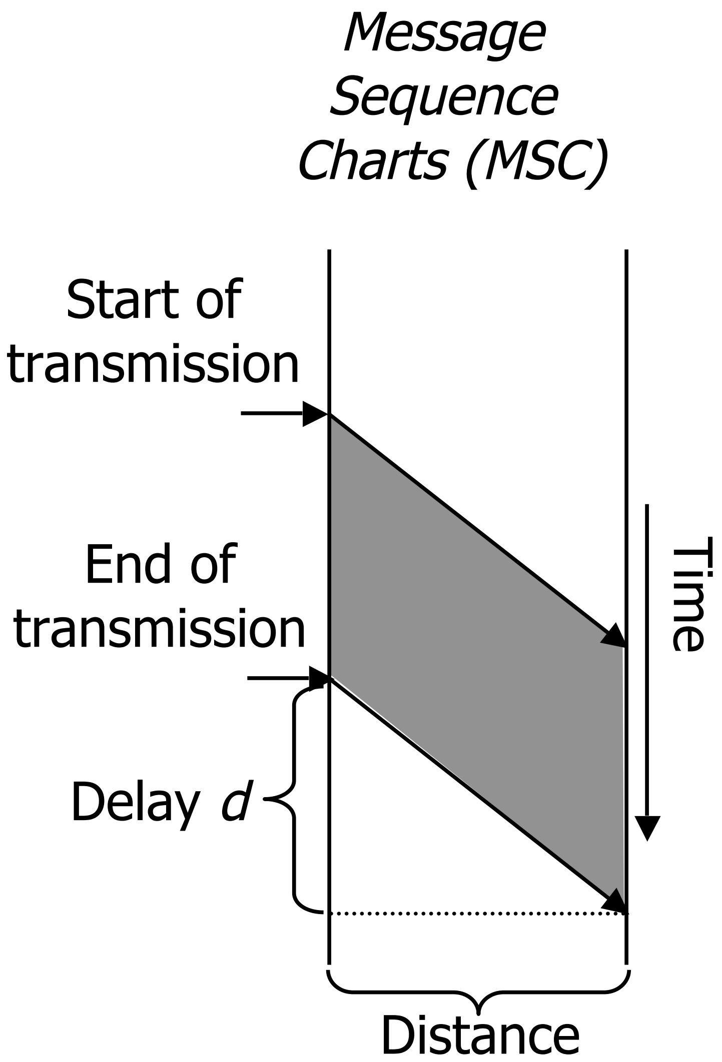
Communication basics

- **Information: Human interpretation**
- **Data: Formalized representation**
- **Signal: Representation of data by characteristic changes of a physical variable**



Signals propagate in medium, store data

- **Signals traveling in a medium take time to reach destination –** *delay d*
  - Depends on distance and propagation speed in transmission medium
- **To represent one or several bits, a signal extending in time is needed –** *duration of transmission*
  - Determined by rate ***r*** and data size
- **During time d, r*d bits are generated**
  - Stored in the medium



Basic organization of communication

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- ***Duplexing***: Given *a single pair* of communicating peers, duplexing describes rules when each peer is allowed to send to the other one
  - Using which resource
- ***Mutiplexing***: Given *several pairs*, multiplexing describes when which pair, using which resources, is allowed to communicate
- Main resources: Time, frequency (+ some others)
- Example combinations?

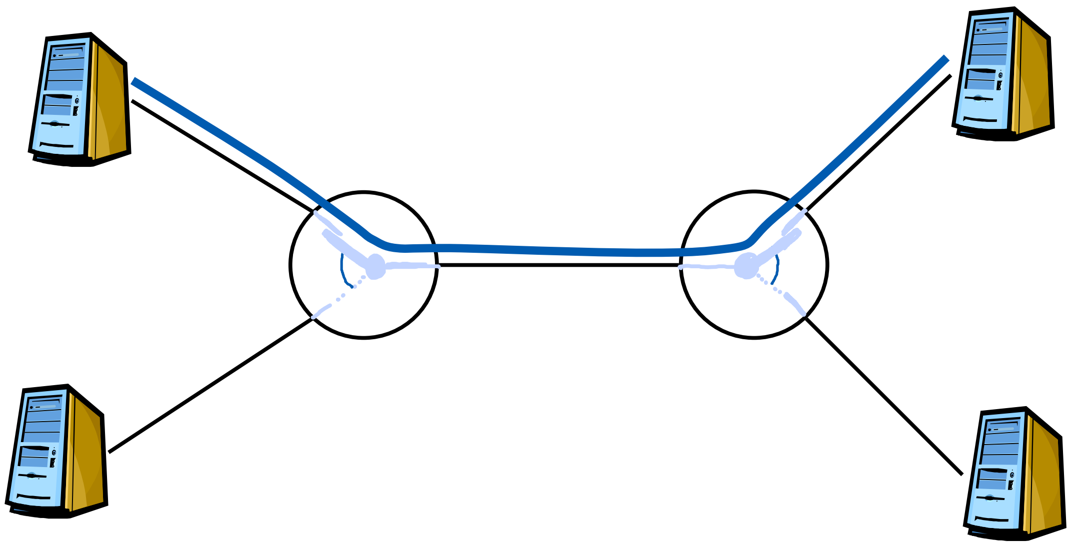
Multiplexing & shared resources

- **Multiplexing can be viewed as a means to regulate the access to a resource that is shared by multiple users**
  - The switching element/its outgoing line
  - With the switching element as the controller
- **Are there other examples of "shared resources"?**
  - Classroom, with "air" as physical medium
  - A shared copper wire, as opposed to direct connection
- **Characteristic: a *broadcast* medium!**

How to realize multiple hops: Switching

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

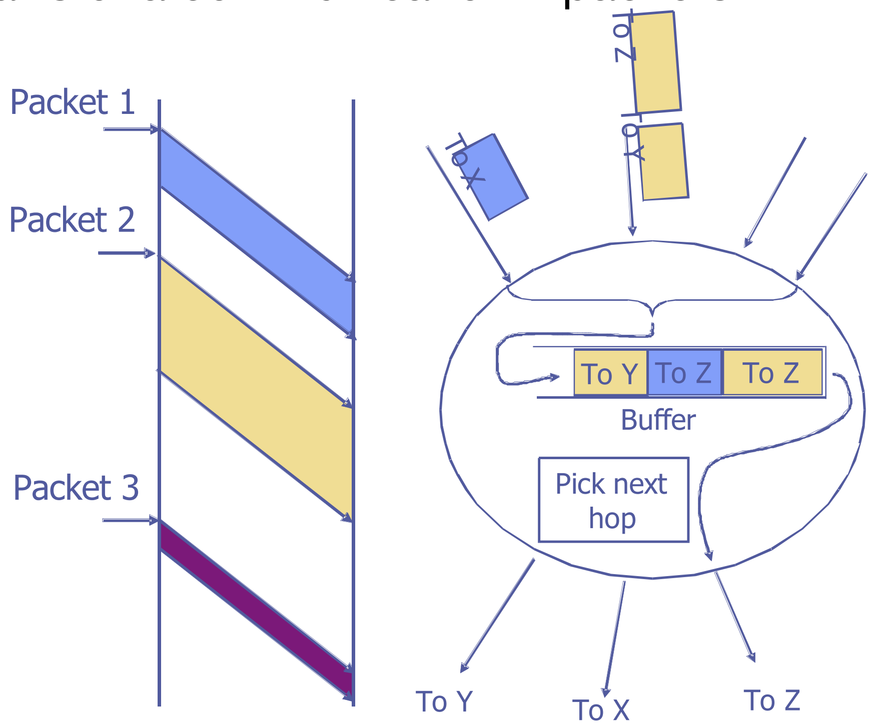
- **In absence of direct connection between communicating peers, some sort of switching becomes necessary**
- Option 1: ***Circuit switching***
  - Request a (physical) connection
  - Turn knobs, switches, etc.
  - Use this connection as before – peers are now directly connected



http://www.wdrcobg.com/switchboard.html

Packet Switching

- Option 2: ***Packet switching***
  - Instead of building and releasing an end-to-end connection for each communication's entire length, only
    - Use connections from one hop to another hop
    - Communicate well identified parts of a communication – packets – between these hop neighbors



University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Routing Tables

- **Packet forwarding**
  - simple lookup gives next hop
- **Routing algorithms**
  - compute the routing tables

Routing table of W

Destination

Neighbor	M	P	Z
U	2	3	4
V	3	2	3
X	4	3	2
Y	4	4	3

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Handling errors

- **Transmission errors**
  - Signals are mutilated, not correctly converted to (intended) bits
  - Local issue
- **Packets are missing**
  - Local or end-to-end issue
- **Overload problems**
  - Flow control: Fast sender overruns slow receiver
  - Congestion control: Receiver would be fast enough, but sender injects more packets into network than network is able to handle

- **Where and how to handle these errors?**

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Typical examples of services

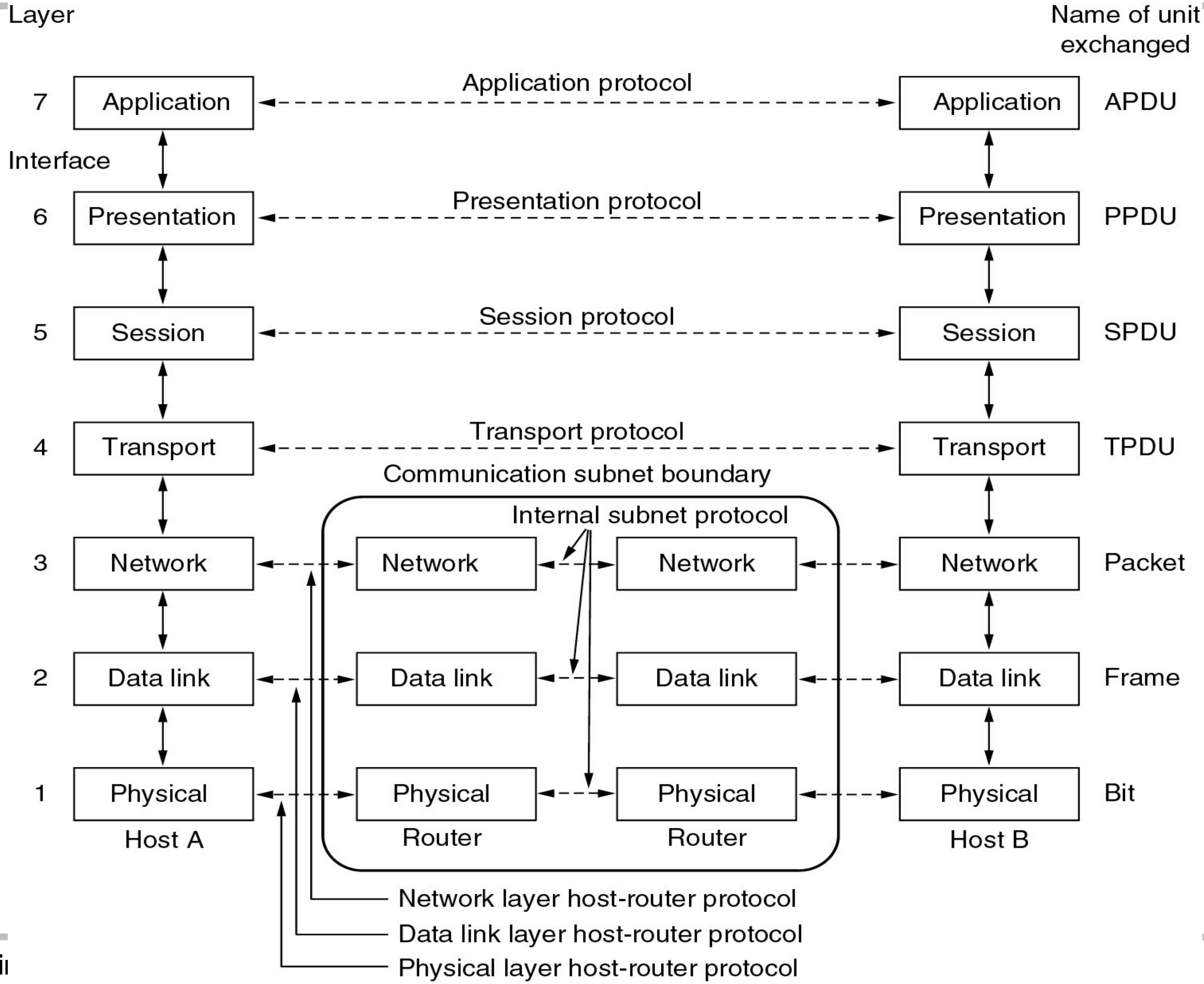
- *Datagram service*
  - Unit of data are messages
  - Correct, but not necessarily complete or in order
  - Connection-less
  - Usually insecure/not dependable, not confirmed

- *Reliable byte stream*
  - Byte stream
  - Correct, complete, in order, confirmed
  - Sometimes, but not always secure/dependable
  - Connection-oriented

- **Almost all possible combinations are conceivable!**

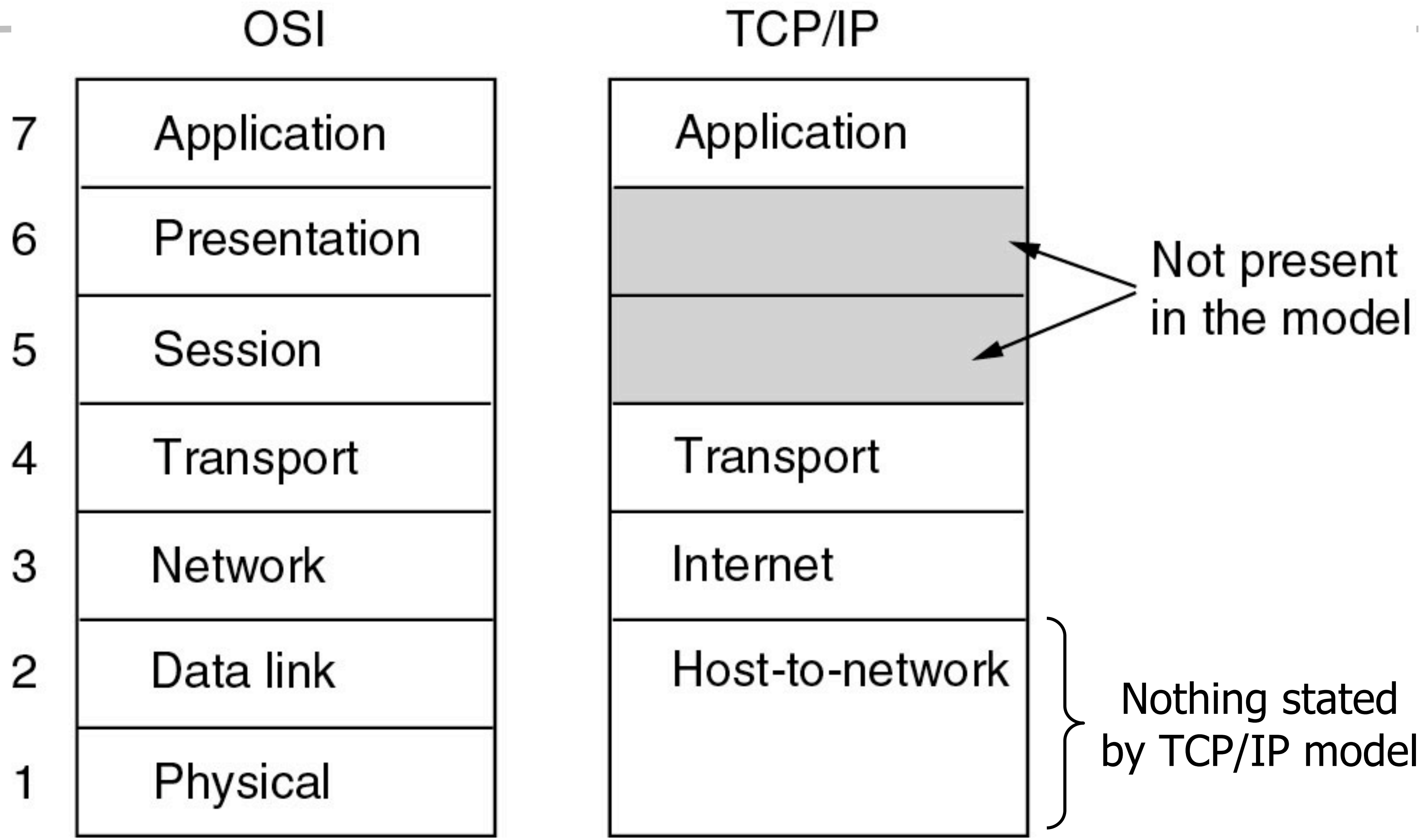
ISO/OSI 7-layer reference model (complete network)

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



TCP/IP protocol stack

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

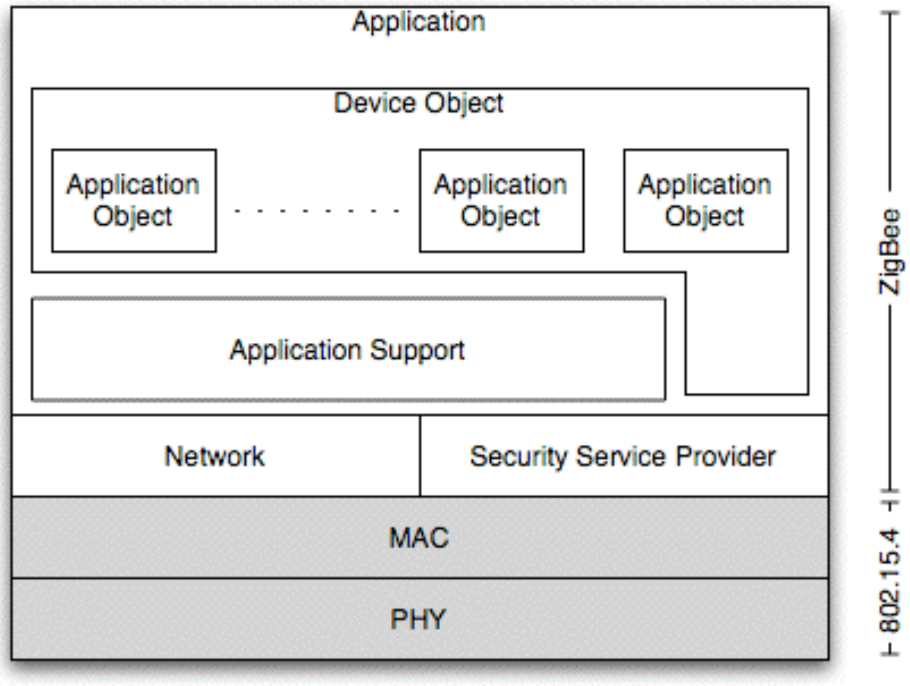


University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Zigbee Protocol Stack

OSI

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical



University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Single node architecture

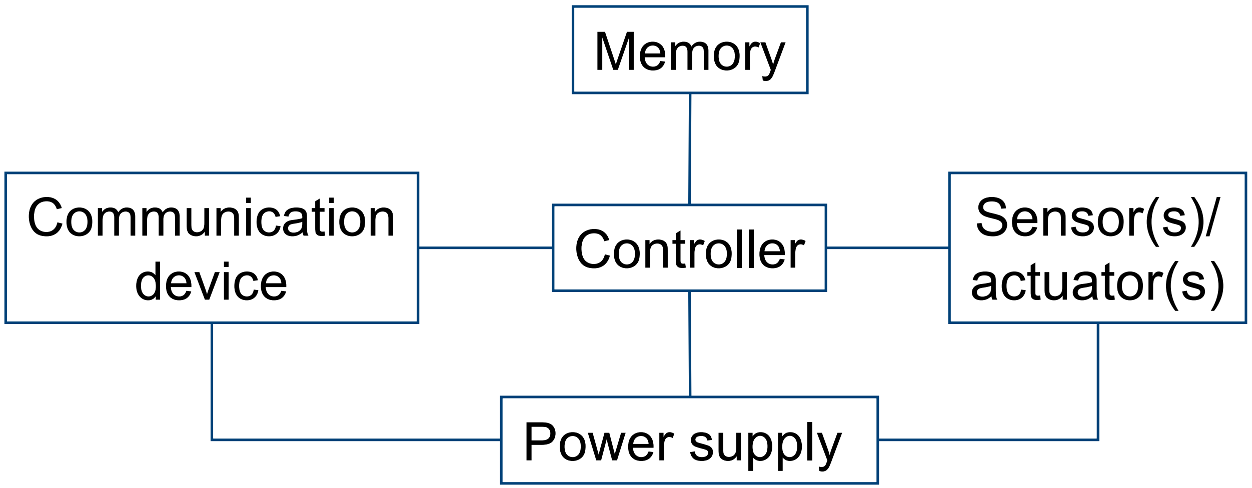
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

Outline

- *Sensor node architecture*
- **Energy supply and consumption**
- **Runtime environments for sensor nodes**
- **Case study: TinyOS**

Sensor node architecture

- **Main components of a WSN node**
  - Controller
  - Communication device(s)
  - Sensors/actuators
  - Memory
  - Power supply



Controller

- **Main options:**
  - Microcontroller – general purpose processor, optimized for embedded applications, low power consumption, cheap
  - FPGAs – not optimized for energy consumption
  - ASICs – best solution, but very expensive

- **Example microcontrollers**
  - Texas Instruments MSP430
    - 16-bit RISC core, up to 4 MHz, versions with 2-10 kbytes RAM, several DACs, RT clock
  - Atmel ATMega
    - 8-bit controller, larger memory than MSP430, slower

Communication device

- **Which transmission medium?**
  - Electromagnetic at radio frequencies? ✓
  - Electromagnetic, light?
  - Ultrasound?

Physics of Electro-magnetic Waves

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- Frequency f: number of oscilations per second
  - unit of measurement : **Hertz**
  - **wave length λ:** distance (in meters) between wave maxima
  - The propagation speed of waves in vacuum is constant:
  - **speed of light c ≈ 3 · 10^8 m/s**

- Note that:

$$\lambda \cdot f = c$$

Thank you

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

CoNe Freiburg

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

Wireless Sensor Networks
Christian Schindelhauer
schindel@informatik.uni-freiburg.de

3rd Lecture
31.10.2006