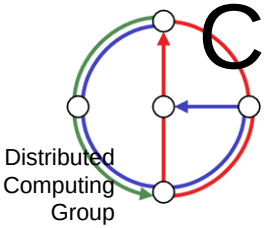
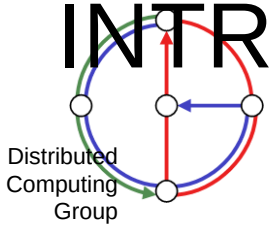
MOBILE COMPUTING



Roger Wattenhofer

Winter 2005 / 2006

Chapter 1 INTRODUCTION



Mobile Computing

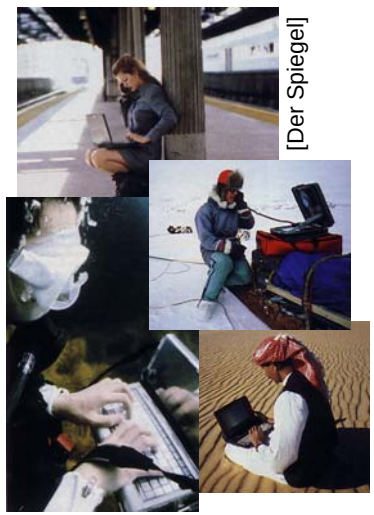
Winter 2005 / 2006

Overview

- What is it?
- Who needs it?
- History
- Future

- Course overview
- Organization of exercises
- Literature

- Thanks to J. Schiller for slides



[Der Spiegel]

A computer in 2010?

- Advances in technology
  - More computing power in smaller devices
  - Flat, lightweight displays with low power consumption
  - New user interfaces due to small dimensions
  - More bandwidth (per second? per space?)
  - Multiple wireless techniques
- Technology in the background
  - Device location awareness: computers adapt to their environment
  - User location awareness: computers recognize the location of the user and react appropriately (call forwarding)
- “Computers” evolve
  - Small, cheap, portable, replaceable
  - Integration or disintegration?

What is *Mobile* Computing?

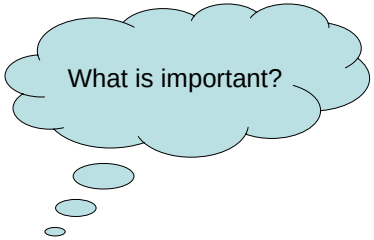
- Aspects of mobility
  - User mobility: users communicate “anytime, anywhere, with anyone” (example: read/write email on web browser)
  - Device portability: devices can be connected anytime, anywhere to the network
- Wireless vs. mobile Examples

✗	✗	Stationary computer
✗	✓	Notebook in a hotel
✓	✗	Wireless LANs in historic buildings
✓	✓	Personal Digital Assistant (PDA)

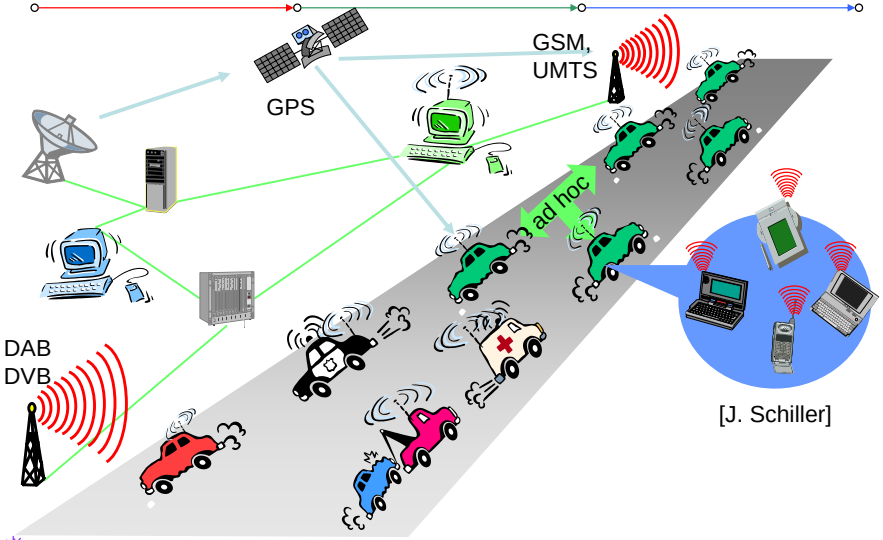
- The demand for mobile communication creates the need for integration of wireless networks and existing fixed networks
  - Local area networks: standardization of IEEE 802.11 or HIPERLAN
  - Wide area networks: GSM and ISDN
  - Internet: Mobile IP extension of the Internet protocol IP

Application Scenarios

- Vehicles
- Nomadic user
- Smart mobile phone
- Invisible computing
- Wearable computing
- Intelligent house or office
- Meeting room/conference
- Taxi/Police/Fire squad fleet
- Service worker
- Lonely wolf
- Disaster relief and Disaster alarm
- Games
- Military / Security

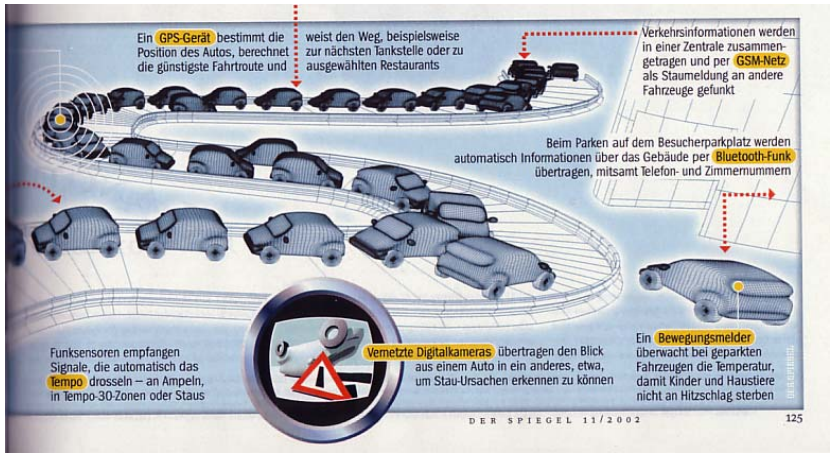


Vehicles



[J. Schiller]

Vehicles 2



[Der Spiegel]

Nomadic user

- Nomadic user has laptop/palmtop
- Connect to network infrequently
- Interim period operate in disconnected mode
- Access her or customer data
- Consistent database for all agents
- Print on local printer (or other service)
  - How do we find it?
  - Is it safe?
  - Do we need wires?

- Does nomadic user need her own hardware?
  - Read/write email on web browser
  - Access data OK too

Smart mobile phone/device

- Converge with PDA?
- Voice calls, video calls (really?)
- Email or instant messaging
- Play games
- Up-to-date localized information
  - Map
  - Pull: Find the next Pizzeria
  - Push: “Hey, we have great Pizza!”
- Stock/weather/sports info
- Ticketing
- Trade stock
- etc.

[Blackberry]

[J. Schiller]

- Connecting Devices (Bluetooth)

Invisible/ubiquitous/pervasive and wearable computing

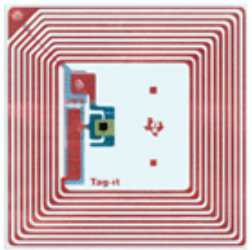
- Tiny embedded “computers”
- Everywhere
- Example: Microsoft’s Doll

- I refer to my colleagues Friedemann Mattern and Bernt Schiele and their courses

[ABC, Schiele]

Object Tracking: RFID

- Book, pallet, packet, airline baggage, container, truck tracking
- Identification badges for building/car access control or animal identfication
- Electronic toll collection
- Electronic cash in smart cards or credit cards
- Prisoner tracking
- Store checkout as cashier replacement



Intelligent Office and Intelligent House

- Bluetooth replaces cables
- Plug and play, without the “plug”
- Again: Find the local printer

- House recognizes inhabitant
- House regulates temperature according to person in a room
- Typical application of sensor/actor network

[MS]

- Trade Shows
- Home without cables looks better
- LAN in historic buildings

Meeting Room or Conference

- Share data instantly
- Send a message to someone else in the room
- Secretly vote on controversial issue
- Find person with similar interests
- Broadcast last minute changes

- Ad-Hoc Network

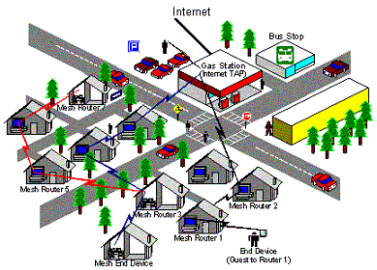
- e.g. Shockfish SpotMe

Community Mesh Networking

- Neighbors cooperate and forward each others packets; fewer gateways to the Internet needed.

- Neighbors can cooperatively deploy backup technology.

- Local information and community building:
  - “Who has a high pressure cleaner?”



- “Bill Gated Community”

Taxi / Police / Fire squad / Service fleet

- Connect
- Control
- Communicate

- Service Worker
- Example: SBB service workers have PDA
  - Map help finding broken signal
  - PDA gives type of signal, so that service person can bring the right tools right away

Lonely wolf

- We really mean *everywhere*!
- Cargo's and yachts
- Journalists
- Scientists
- Travelers
- Sometimes cheaper than infrastructure?
- Commercial flop

[Motorola]

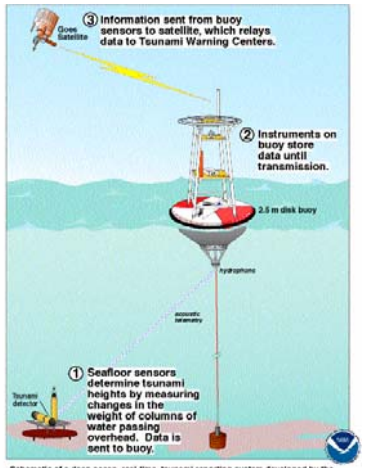
Disaster relief

- After earthquake, tsunami, volcano, etc:
- You cannot rely on infrastructure but you need to orchestrate disaster relief
- Early transmission of patient data to hospital
- Satellite
- Ad-Hoc network

[Red Cross]

Disaster alarm

- With sensors you might be able to alarm early
- Example: Tsunami
- Example: Cooling room
- Or simpler: Weather station
- Satellite
- Ad-Hoc network



Schematic of a deep-ocean, real-time, tsunami reporting system developed by the National Oceanic and Atmospheric Administration (NOAA).

Games

- Nintendo Gameboy [Advance]: Industry standard mobile game station
- Connectable to other Gameboys
- Can be used as game pad for Nintendo Gamecube
- Cybiko [Extreme] is a competitor that has radio capabilities built in
- Second generation already
- Also email, chat, etc.

[Cybiko]

Military / Security

- From a technology standpoint this is similar to disaster relief
- Sensoria says “US army is the best costumer”
- Not (important) in this course

[Der Spiegel]

Application Scenarios: **Discussion**

- Vehicles
- Nomadic user
- Smart mobile phone
- Invisible computing
- Wearable computing
- Intelligent house or office
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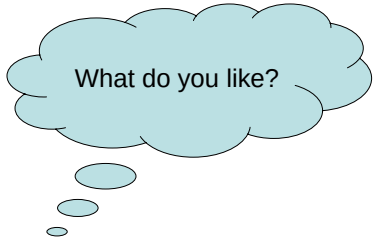
- Disaster relief and Disaster alarm
- Games
- Military / Security
- **Anything missing?**



Mobile devices

Pager
• receive only
• tiny displays
• simple text messages

PDA
• simple graphical displays
• character recognition
• simplified WWW

Laptop
• fully functional
• standard applications

Sensors, embedded controllers

Mobile phone
• voice, data
• simple text display

Palmtop
• tiny keyboard
• simple versions of standard applications

performance and size

What do you have? What would you buy?

- Laptop (Linux, Mac, Windows?)
- Palmtop (Linux, Mac, Windows?)
- PDA/Organizer (Palm, Pocket PC, other?)
- Mobile phone
- Satellite phone
- Pager
- Wireless LAN Card
- Wireless LAN Base Station (for home networking)
- Ethernet Plug in every room (for home networking)
- Bluetooth
- GPS
- Proprietary device (what kind?)

Effects of device portability

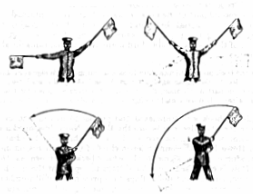
- Energy consumption
  - there is no Moore's law for batteries or solar cells
  - limited computing power, low quality displays, small disks
  - Limited memory (no moving parts)
  - Radio transmission has a high energy consumption
  - CPU: power consumption ~ CV^2f
    - C: total capacitance, reduced by integration
    - V: supply voltage, can be reduced to a certain limit
    - f: clock frequency, can be reduced temporally
- Limited user interfaces
  - compromise between size of fingers and portability
  - integration of character/voice recognition, abstract symbols
- Loss of data
  - higher probability (e.g., defects, theft)

Wireless networks in comparison to fixed networks

- Higher loss-rates due to interference
  - emissions of, e.g., engines, lightning
- Restrictive regulations of frequencies
  - frequencies have to be coordinated, useful frequencies are almost all occupied
- Low transmission rates
  - local some Mbit/s, regional currently, e.g., 9.6kbit/s with GSM
- Higher delays, more jitter
  - connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems, tens of seconds with Bluetooth
- Lower security, simpler active attacking
  - radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
- Always shared medium
  - secure access mechanisms important

History: Antiquity – 1890

- Many people in history used light for communication
  - Heliographs (sun on mirrors), flags („semaphore"), ...
  - 150 BC: smoke signals for communication (Polybius, Greece)
  - 1794: Optical telegraph by Claude Chappe



- Electromagnetic waves
  - 1831: Michael Faraday (and Joseph Henry) demonstrate electromagnetic induction
  - 1864: James Maxwell (1831-79): Theory of electromagnetic fields, wave equations
  - 1886: Heinrich Hertz (1857-94): demonstrates with an experiment the wave character of electrical transmission through space

History: 1890 – 1920

- 1895: Guglielmo Marconi (1874 – 1937)
  - first demonstration of wireless telegraphy (digital!)
  - long wave transmission, high transmission power necessary (> 200kW)
  - Nobel Prize in Physics 1909

- 1901: First transatlantic connection
- 1906 (Xmas): First radio broadcast
- 1906: Vacuum tube invented
  - By Lee DeForest and Robert von Lieben
- 1907: Commercial transatlantic connections
  - huge base stations (30 100m high antennas)
- 1911: First mobile sender
  - on board of a Zeppelin
- 1915: Wireless voice transmission NY – SF
- 1920: First commercial radio station

History: 1920 – 1945

- 1920: Discovery of short waves by Marconi
  - reflection at the ionosphere
  - smaller sender and receiver
  - Possible with vacuum tube
- 1926: First phone on a train
  - Hamburg – Berlin
  - wires parallel to the railroad track
- 1926: First car radio
- 1928: First TV broadcast
  - John L. Baird (1888 – 1946)
  - Atlantic, color TV
  - WGY Schenectady
- 1933: Frequency modulation
  - Edwin H. Armstrong (1890 – 1954)

History: 1945 – 1980

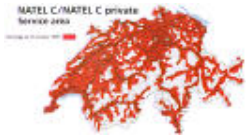
- 1958: German A-Netz
  - Analog, 160MHz, connection setup only from mobile station, no handover, 80% coverage, 16kg, 15k Marks
  - 1971: 11000 customers
  - Compare with PTT (Swisscom) NATEL: 1978 – 1995, maximum capacity 4000, which was reached 1980

[F.Mattern]

- 1972: German B-Netz
  - Analog, 160MHz, connection setup from the fixed network too (but location of the mobile station has to be known)
  - available also in A, NL and LUX, 1979 13000 customer in D
  - PTT NATEL B: 1984 – 1997, maximum capacity 9000
- 1979: NMT Nordic Mobile Telephone System
  - 450MHz (Scandinavia)

History: 1980 – 1991

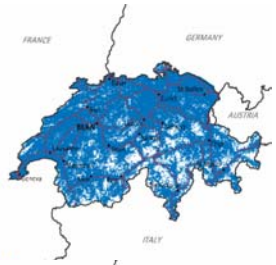
- 1982: Start of GSM-specification (Groupe spéciale mobile)
  - goal: pan-European *digital* mobile phone system with *roaming*
- 1984: CT-1 standard for cordless telephones
- 1986: German C-Netz
  - analog voice transmission, 450MHz, hand-over possible, digital signaling, automatic location of mobile device
  - still in use today, services: FAX, modem, X.25, e-mail, 98% coverage
  - American AMPS: 1983 – today
  - PTT NATEL C: 1986 – 1999



- 1991: DECT
  - Digital European Cordless Telephone. Today: “Enhanced”
  - 1880-1900MHz, ~100-500m range, 120 duplex channels, 1.2Mbit/s data transmission, voice encryption, authentication, up to several 10000 users/km^2, used in more than 40 countries

History: 1991 – 1995

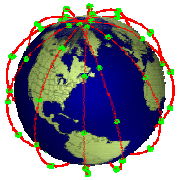
- 1992/3: Start of GSM “D-Netz”/“NATEL D”
  - 900MHz, 124 channels
  - automatic location, hand-over, cellular
  - roaming in Europe
  - now worldwide in more than 130 countries
  - services: data with 9.6kbit/s, FAX, voice, ...



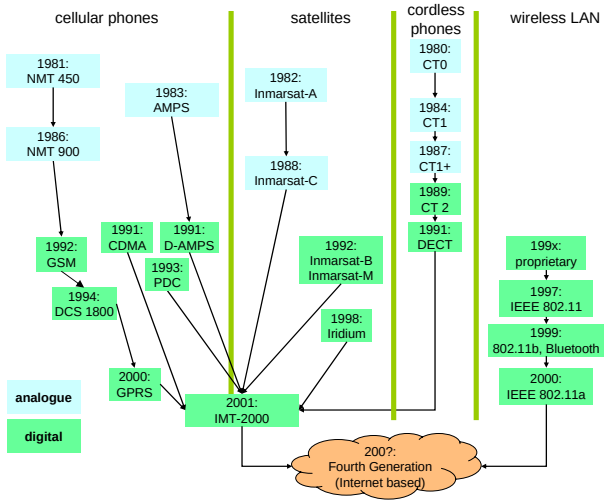
- 1994/5: GSM with 1800MHz
  - smaller cells
  - supported by many countries
  - SMS
  - Multiband phones

History: 1995 – today

- 1996: HiperLAN
  - High Performance Radio Local Area Network
  - Products?
- 1997: Wireless LAN
  - IEEE 802.11
  - 2.4 – 2.5 GHz and infrared, 2Mbit/s
  - already many products (with proprietary extensions)
- 1998: Specification of GSM successors
  - GPRS is packet oriented
  - UMTS is European proposal for IMT-2000
- 1998: Iridium
  - 66 satellites (+6 spare)
  - 1.6GHz to the mobile phone



Wireless systems: overview of the development

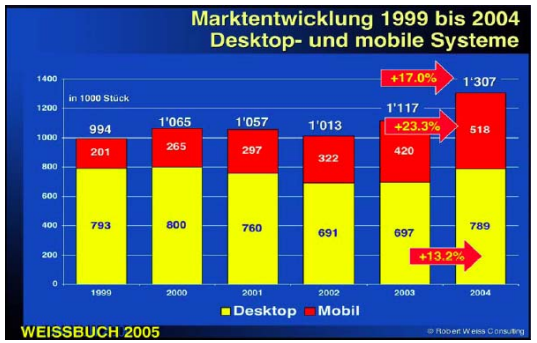


The future: ITU-R - Recommendations for IMT-2000

- M.687-2
  - IMT-2000 concepts and goals
- M.816-1
  - framework for services
- M.817
  - IMT-2000 network architectures
- M.818-1
  - satellites in IMT-2000
- M.819-2
  - IMT-2000 for developing countries
- M.1034-1
  - requirements for the radio interface(s)
- M.1035
  - framework for radio interface(s) and radio sub-system functions
- M.1036
  - spectrum considerations
- M.1078
  - security in IMT-2000
- M.1079
  - speech/voiceband data performance
- M.1167
  - framework for satellites
- M.1168
  - framework for management
- M.1223
  - evaluation of security mechanisms
- M.1224
  - vocabulary for IMT-2000
- M.1225
  - evaluation of transmission technologies
- etc.
- **www.itu.int/imt**

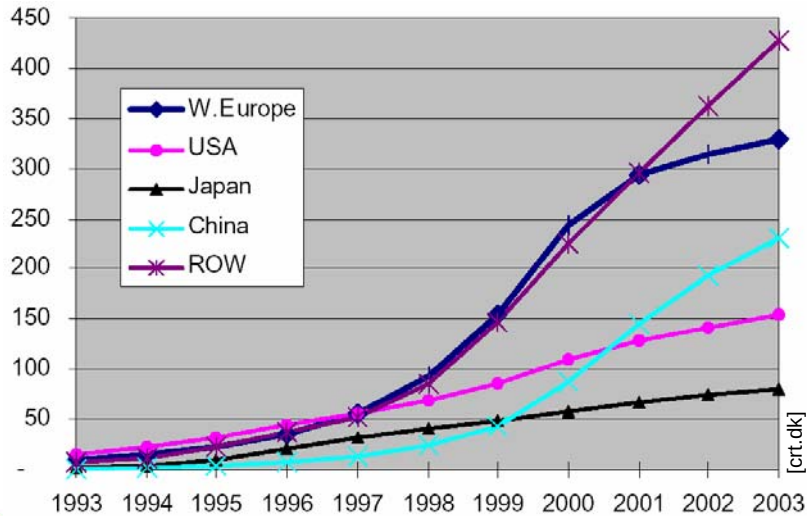
The success story of “Mobile Computing”

- Mobile Phones
  - Switzerland February 2002: More mobile phones than fixnet phones
  - Worldwide: More mobile phones than Internet connections
  - SMS: “More net profit with SMS than with voice”
- Laptops
  - Switzerland: Market share of mobile machines growing

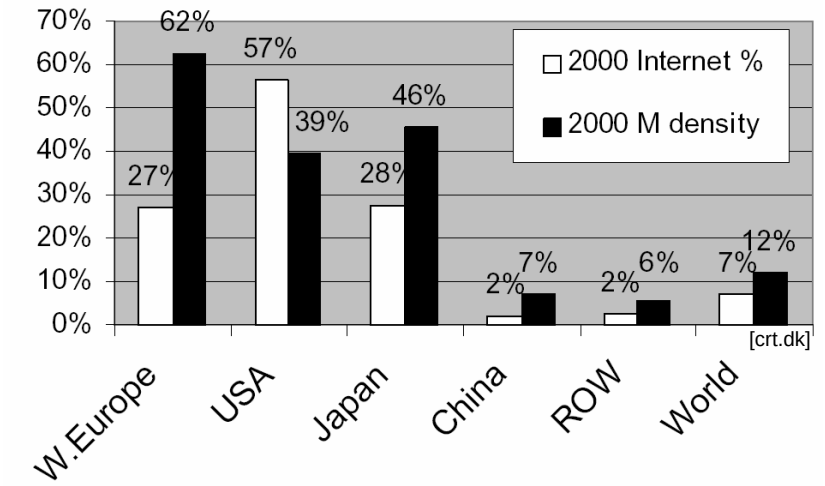


[R.Weiss]

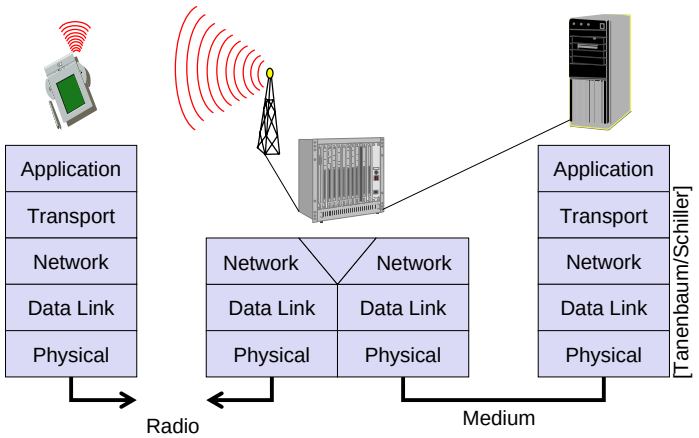
Mobile phones worldwide



Internet vs. Mobile phones



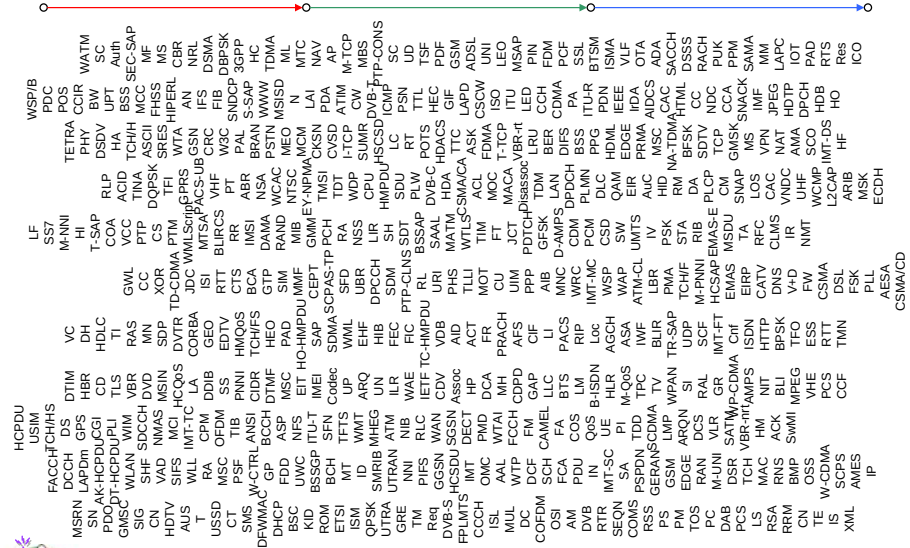
Simple reference model



Course overview: Networking Bottom – Up Approach

- Application layer
  - service location
  - new applications, multimedia
  - adaptive applications
  - congestion and flow control
- Transport layer
  - quality of service
  - addressing, routing, device location
- Network layer
  - hand-over
  - authentication
- Data link layer
  - media access
  - multiplexing
  - media access control
  - encryption
- Physical layer
  - modulation
  - interference
  - attenuation
  - frequency

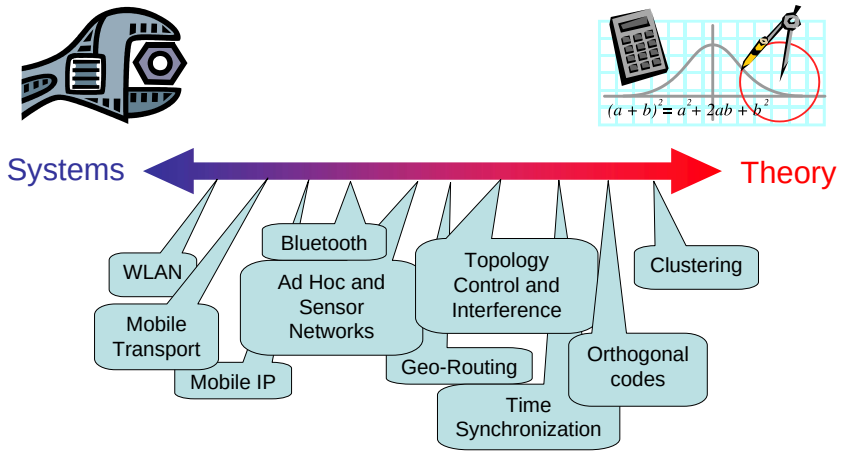
Course Overview: Acronyms



Course overview: Lectures and *Exercises*

Introduction	*Hard- and Software Tests*
Physical and Link Layer	*"Hello World"*
WLAN	*Theory: Codes/MAC*
Media Access Control	*Neighbor Detection*
Mobile IP & TCP	*Instant Messenger*
Ad Hoc and Sensor Networks	*Topology Detection*
Geometric Routing	*Multihop Routing 1*
Clustering	*Multihop Routing 2*
Topology Control & Interference	*Theory: Ad-Hoc Networks*
Data Gathering	*Multihop Project 1*
Time Synchronization	*Multihop Project 2*
Localization / Positioning	*Multihop Project 3*

Course overview: A large spectrum



Course specialties

- Maximum possible spectrum of systems and theory
- New area, more open than closed questions
- Lecture and exercises are hard to synchronize

- New this year: Focus on ad hoc and sensor networks

- dcg.ethz.ch → courses

Literature

- Jochen Schiller – *Mobile Communications / Mobilkommunikation*
- Charles E. Perkins – *Ad-hoc networking*
- Andrew Tanenbaum – *Computer Networks, plus other books*
- Ivan Stojmeniovic – *Handbook of Wireless Networks and Mobile Computing*
- C. Siva Murthy and B. S. Manoj – *Ad Hoc Wireless Networks*

- *Selected chapters from upcoming book on Ad Hoc and Sensor Networks edited by Dorothea Wagner and Roger Wattenhofer*

- *Plus tons of other books/articles on specialized topics*
- *Papers, papers, papers, …*

Famous last words

"Mobile wireless computers are like mobile pipeless bathrooms – portapotties. They will be common on vehicles, and at construction sites, and rock concerts. My advice is to wire up your home and stay there."

Bob Metcalfe, 1995
(Ethernet inventor)