MOBILE COMPUTING

Roger Wattenhofer

Summer 2002

Distributed Computing Group

Chapter 1 INTRODUCTION
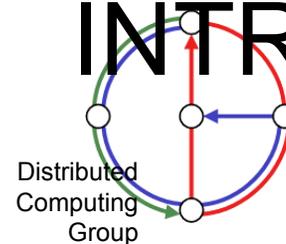
Mobile Computing

Summer 2002

Distributed Computing Group

Overview

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

- Course overview
- Organization of exercises
- Literature

- Thanks to J. Schiller for slides

[Der Spiegel]
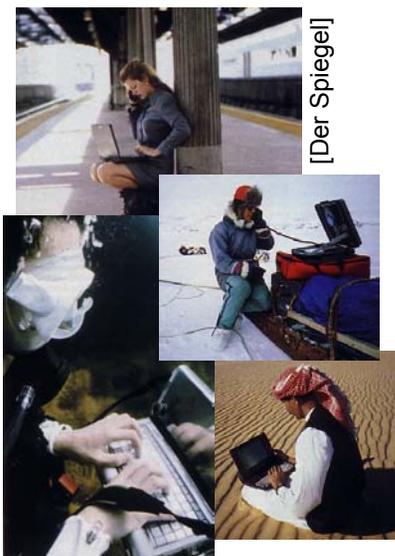
A computer in 2010?

- 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

What is important?

Vehicles

GPS

GSM, UMTS

ad hoc

DAB

[J. Schiller]

Vehicles 2

[Der Spiegel]
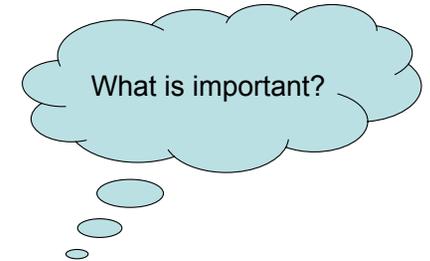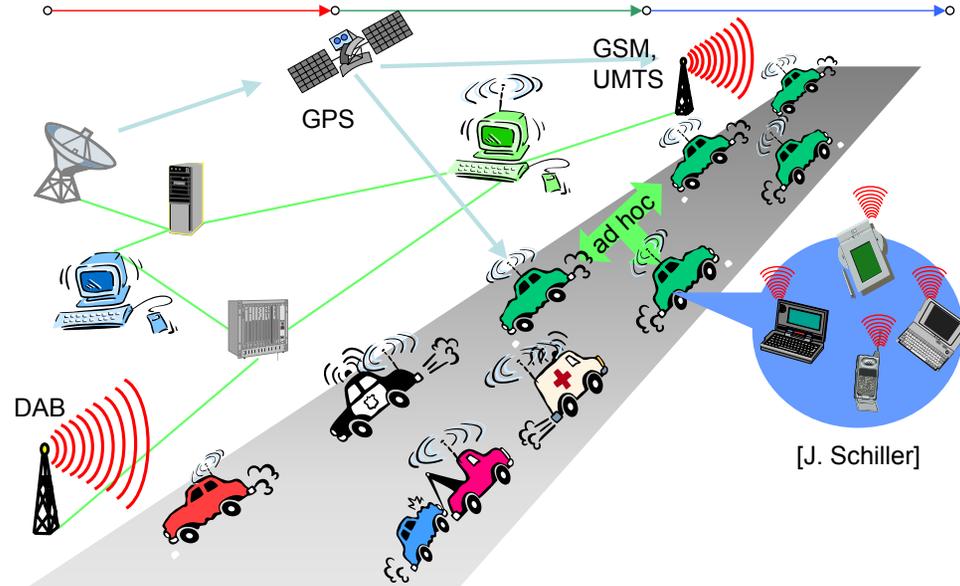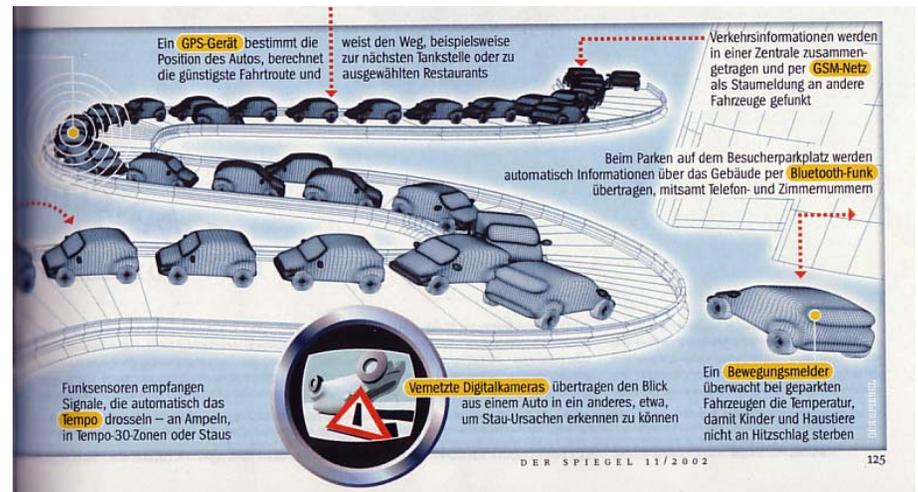
Nomadic user

- 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

- Mobile phones get smarter
- 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.

[Nokia]

[J. Schiller]

Built 150BC

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]

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

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

[MS]

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

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 hospical

- 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

③ Information sent from buoy sensors to satellite, which relays data to Tsunami Warning Centers.

② Instruments on buoy store data until transmission.

2.5 m disk buoy

hydrophone

acoustic telemetry

① Seafloor sensors determine tsunami heights by measuring changes in the weight of columns of water passing overhead. Data is sent to buoy.
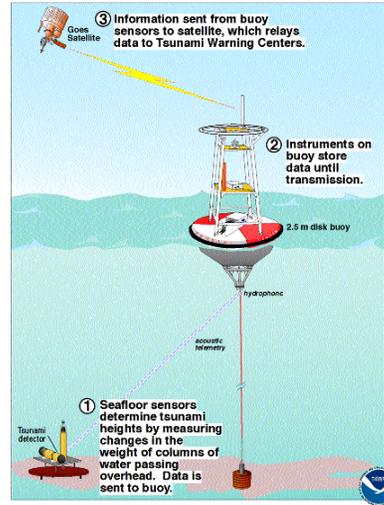
Schematic of a deep ocean, real-time, tsunami reporting system developed by the National Oceanic and Atmospheric Administration (NOAA).

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
- Meeting room/conference
- Taxi/Police/Fire squad fleet
- Service worker
- Lonely wolf
- Disaster relief and Disaster alarm
- Games
- Military / Security
- **Anything missing?**

What do you like?

Mobile devices

Pager
• receive only
• tiny displays
• simple text messages

Sensors, embedded controllers

PDA
• simple graphical displays
• character recognition
• simplified WWW

Laptop
• fully functional
• standard applications

Mobile phone
• voice, data
• simple text display

Palmtop
• tiny keyboard
• simple versions of standard applications

performance and size
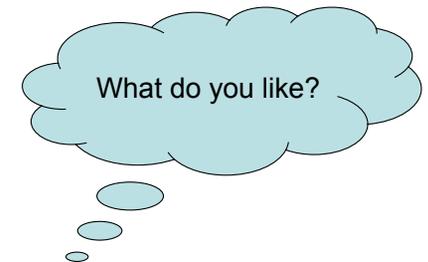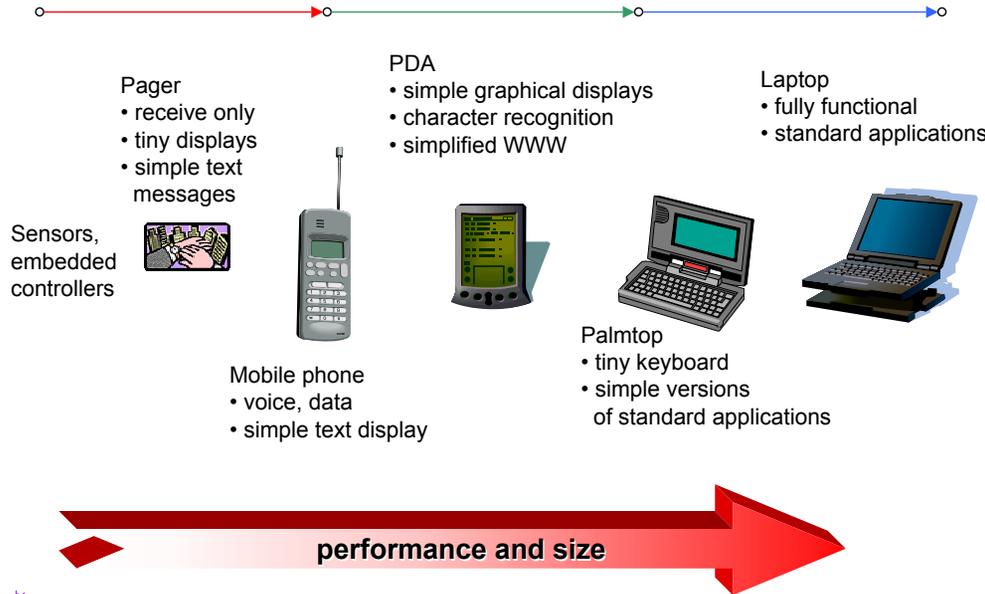
What do you have? What would you buy?

• 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
• Proprietary device (what kind?)

for exercises ✗

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
• More 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
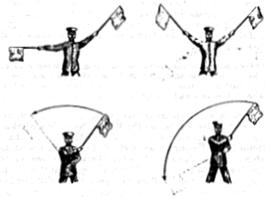
History: 1890 – 1920

- 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
- 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)

[F.Mattern]

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
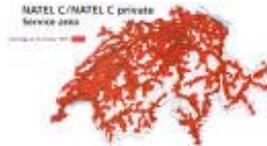
History: 1991 – 1995

- 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
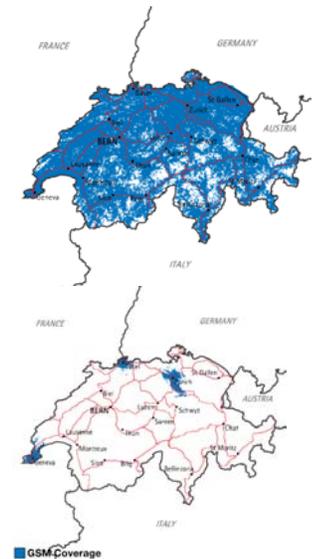
History: 1995 – today

- 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
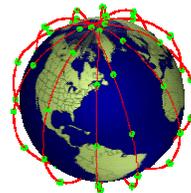
Wireless systems: overview of the development

cellular phones | satellites | cordless phones | wireless LAN

analog
digital
[J. Schiller]

1981: NMT 450
1986: NMT 900
1983: AMPS
1991: CDMA
1991: D-AMPS
1992: GSM
1993: PDC
1994: DCS 1800
1982: Inmarsat-A
1988: Inmarsat-C
1992: Inmarsat-B Inmarsat-M
1998: Iridium
1980: CT0
1984: CT1
1987: CT1+
1989: CT 2
1991: DECT
199x: proprietary
1995/96/97: IEEE 802.11, HIPERLAN
2005?: UMTS/IMT-2000
2005?: MBS, WATM

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 2001: For the first year less computers sold, but *more* mobile computers; private households buy 18% more laptops than the previous year.


[R.Weiss]
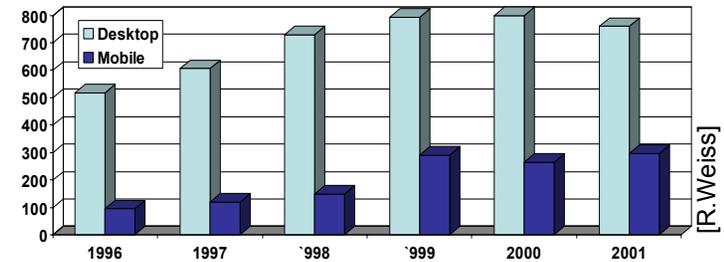
Mobile phones worldwide

[crt.dk]
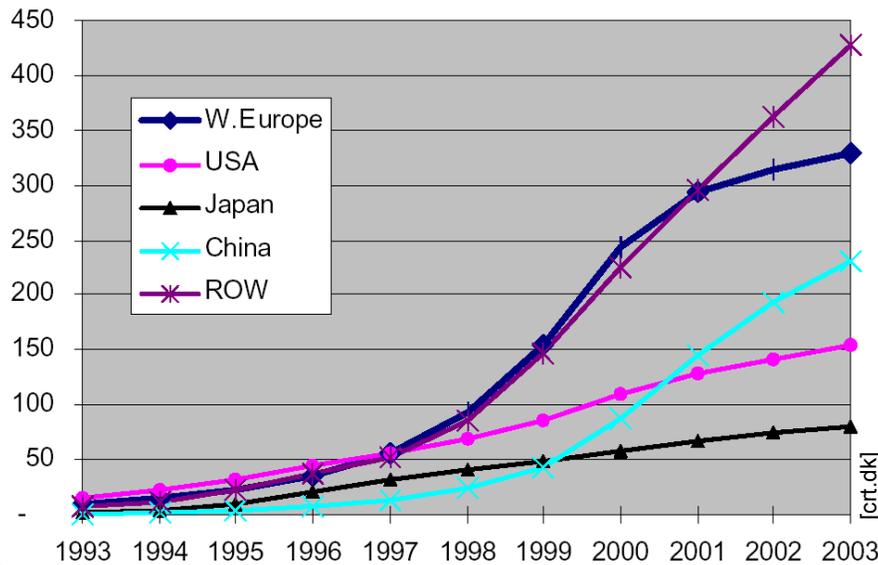
Mobile phones Top 12

[crt.dk]
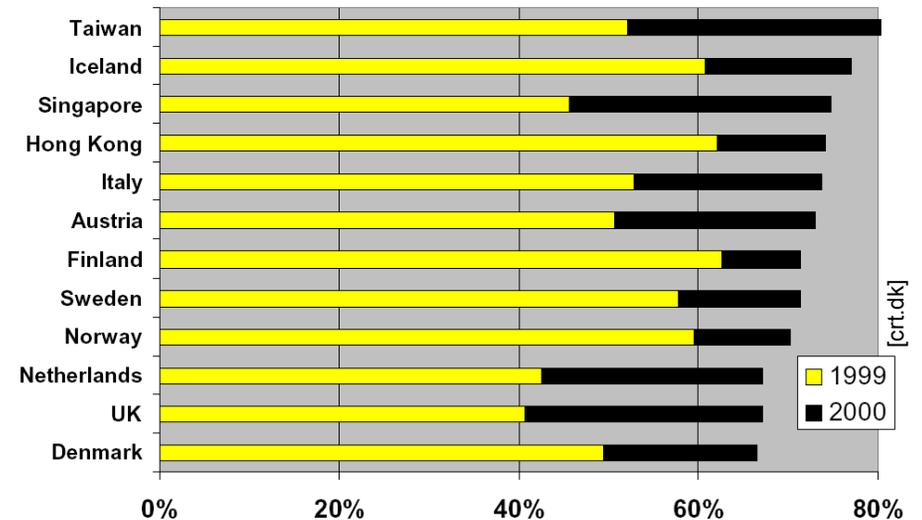
Mobile phones saturation

Legend:
- Max. density (1+2)
- Saturation level, uniques (1)
- Saturation, doubles & inactive (2)
- M phone density W.Europe

[crt.dk]
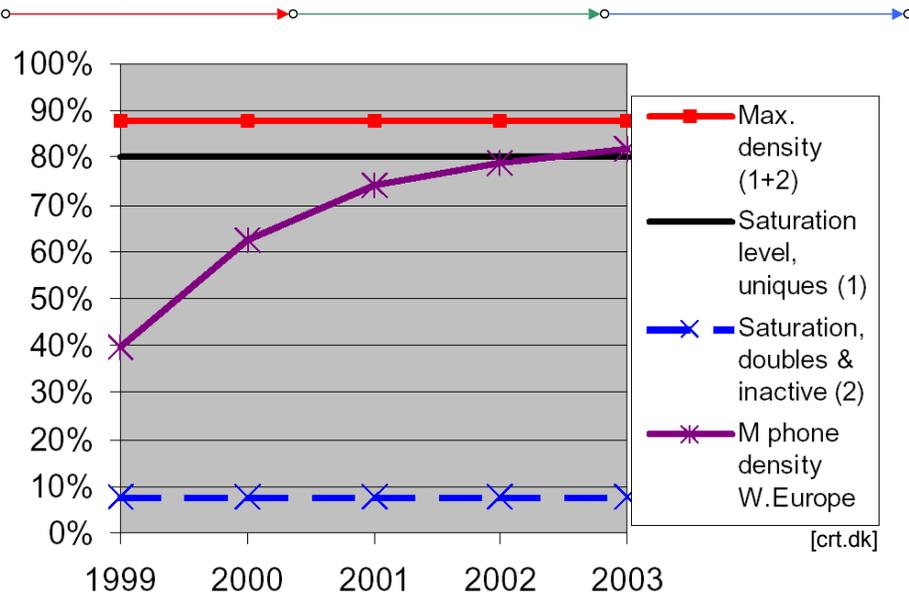
Internet vs. Mobile phones

Legend:
- 2000 Internet %
- 2000 M density

[crt.dk]
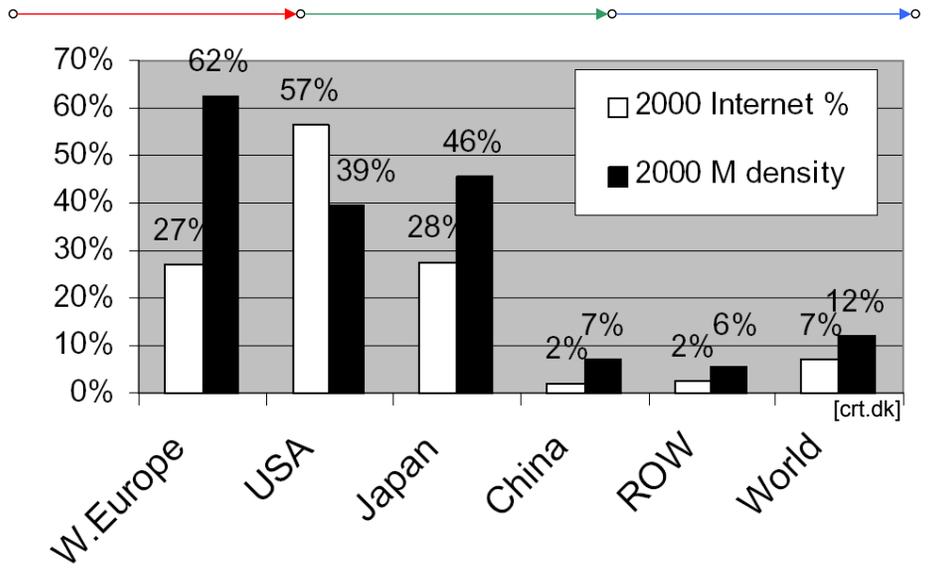
Simple reference model

[Tanenbaum/Schiller]

Radio
Medium
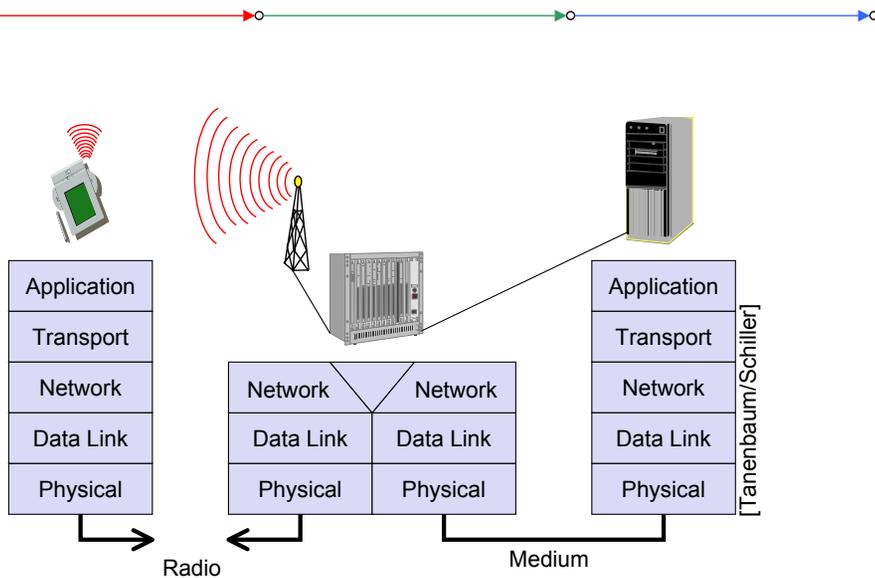
Course overview: Networking Bottom – Up Approach

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

Course Overview: Acronyms

Course overview: A large spectrum

$$(a + b)^2 = a^2 + 2ab + b^2$$

Systems ⟷ Theory

- WAP
- WML and WMLscript
- Bluetooth
- GSM
- How does my wireless LAN card work?
- How do I route in a mobile ad-hoc network?
- Satellites
- Optimal Frequency Allocation
- Orthogonal codes
- How can we access a shared channel?

Course overview: Hands-On Exercises

- We build a wireless LAN based ad-hoc network
  - We start with the "hello world" equivalent
  - Neighbor detection
  - Chat application
  - Multihop routing
  - Multihop chat
  - Multihop game

- Supported by
  - paper exercises
  - WAP exercises

Course overview: Lectures and *Exercises*

Introduction	*Hard- and Software Tests*
Physical and Link Layer	*"Hello World"*
Media Access Control	*Theory: Codes/MAC*
Local Area Networks	*Neighbor Detection / Chat*
Ad-Hoc Networks	*[Auffahrt]*
Ad-Hoc Networks 2	*Multihop Routing*
[Pfingsten]	*Multihop Routing 2*
Mobile IP and TCP	*Multihop Game*
Other Wireless Media Forms	*Multihop Game 2*
Telephony Networks	*Theory: T.b.a.*
Mobile Internet: WAP	*WAP Design*
Mobile Applications	*WAP Implementation*
Conclusion	

Course specialities

- Remember: Course for first time
  - We were clueless about the number of students
  - We were clueless about the availability of systems
  - Assistants are rookies
  - Professor is rooky

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

- http://distcomp.ethz.ch/mobicomp

Literature

- Ivan Stojmeniovic – *Handbook of Wireless Networks and Mobile Computing*
- Jochen Schiller – *Mobile Communications / Mobilkommunikation*
- Andrew Tanenbaum – *Computer Networks, plus other books*
- Hermann Rohling – *Einführung in die Informations– und Codierungstheorie*
- James D. Solomon – *Mobile IP, the Internet unplugged*
- Charles E. Perkins – *Ad-hoc networking*

- *Plus tons of other books 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)