MOBILE COMPUTING

Roger Wattenhofer
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Overview

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

• Course overview
• Organization of exercises
• Literature

• Thanks to J. Schiller for slides
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**
  - 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 2

Ein GPS-Gerät bestimmt die Position des Autos, berechnet die günstigste Fahrtroute und weist den Weg, beispielsweise zur nächsten Tankstelle oder zu ausgewählten Restaurants.

Verkehrsinformationen werden in einer Zentrale zusammengetragen und per GSM-Netz als Staumeldung an andere Fahrzeuge gefunkt.

Beim Parken auf dem Besucherparkplatz werden automatisch Informationen über das Gebäude per Bluetooth-Funk übertragen, mitsamt Telefon- und Zimmernummern.

Funksensoren empfangen Signale, die automatisch das Tempo drosseln – an Ampeln, in Tempo-30-Zonen oder Staus.

Vernetzte Digitalkameras übertragen den Blick aus einem Auto in ein anderes, etwa, um Stau-Ursachen erkennen zu können.

Ein Bewegungsmelder überwacht bei geparkten Fahrzeugen die Temperatur, damit Kinder und Haustiere nicht an Hitzeschlag sterben.

[Dek 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.

• 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 identification
- 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

• 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
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.
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
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?
Mobile devices

Pager
- receive only
- tiny displays
- simple text messages

PDA
- simple graphical displays
- character recognition
- simplified WWW

Sensors, embedded controllers

Mobile phone
- voice, data
- simple text display

Laptop
- fully functional
- standard applications

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 $\sim CV^2f$
    - 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
  – Atlantic, color TV
  – WGY Schenectady

• 1933: Frequency modulation
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)
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/km², 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**
  - 1981: NMT 450
  - 1986: NMT 900
  - 1991: CDMA
  - 1991: D-AMPS
  - 1991: AMPS
  - 1992: GSM
  - 1994: DCS 1800
  - 1993: PDC
  - 1998: Iridium
  - 2000: GPRS
  - 2000: PDC
  - 2001: IMT-2000

- **satellites**
  - 1980: CT0
  - 1981: NMT 450
  - 1982: Inmarsat-A
  - 1983: Inmarsat-A
  - 1988: Inmarsat-C
  - 1988: Inmarsat-B
  - 1990: Inmarsat-M
  - 1991: DECT

- **cordless phones**
  - 1980: CT0
  - 1984: CT1
  - 1997: CT1+
  - 1989: CT 2
  - 1991: DECT

- **wireless LAN**
  - 1990: Inmarsat-C
  - 1997: IEEE 802.11
  - 1999: 802.11b, Bluetooth
  - 2000: IEEE 802.11a
  - 2000: 802.11a

- analogue
- digital

2007: Fourth Generation (Internet based)
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
Mobile phones worldwide

- **W. Europe**
- **USA**
- **Japan**
- **China**
- **ROW**

Year: 1993 to 2003

[crt.dk]
Internet vs. Mobile phones

- W. Europe: 27% Internet, 62% Mobile
- USA: 39% Internet, 28% Mobile
- Japan: 2% Internet, 46% Mobile
- China: 7% Internet, 2% Mobile
- ROW: 7% Internet, 6% Mobile
- World: 12% Internet, 7% Mobile
Simple reference model
### Course overview: Networking Bottom – Up Approach

<table>
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<tr>
<th>Layer</th>
<th>Topics</th>
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<td>Application layer</td>
<td>- service location</td>
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<td>- new applications, multimedia</td>
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<td>- adaptive applications</td>
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<td>- congestion and flow control</td>
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<td>Transport layer</td>
<td>- quality of service</td>
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<td>- addressing, routing, device location</td>
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<td>Network layer</td>
<td>- hand-over</td>
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<td>- authentication</td>
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<td>Data link layer</td>
<td>- media access</td>
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<td>- media access control</td>
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<td>- encryption</td>
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<td>Physical layer</td>
<td>- modulation</td>
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<td>- interference</td>
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<td>- attenuation</td>
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<td>- frequency</td>
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Course Overview: Acronyms
Course overview: Lectures and Exercises

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

- Systems
  - WLAN
  - Mobile Transport
  - Mobile IP
  - Bluetooth
  - Ad Hoc and Sensor Networks
  - Geo-Routing
  - Topology Control and Interference
  - Orthogonal codes
- Theory
  - Clustering
  - Time Synchronization

Mathematical equation: 
\[(a + b)^2 = a^2 + 2ab + b^2\]
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 Stojmenovic – *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, ...*
“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)