MOBILE COMPUTING

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Summer 2002

Distributed Computing Group
Chapter 1
INTRODUCTION
Mobile Computing
Summer 2002
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/Policе/Fire squad fleet
- Service worker
- Lonely wolf
- Disaster relief and Disaster alarm
- Games
- Military / Security

What is important?
Vehicles

GPS

GSM, UMTS

DAB

J. Schiller
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 gefunk.

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 Hitzschlag sterben.

[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.
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 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.

[Der Spiegel]
Application Scenarios: Discussion

- Vehicles
- Nomadic user
- Smart mobile phone
- Invisible computing
- Wearable computing
- Intelligent house or office
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- 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

Mobile phone
- voice, data
- simple text display

PDA
- simple graphical displays
- character recognition
- simplified WWW

Laptop
- fully functional
- standard applications

Palmtop
- tiny keyboard
- simple versions of standard applications

Sensors, embedded controllers

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 $\sim CV^2f$
    - $C$: 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
- 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)
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
  – 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

  - 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
- 1983: AMPS
- 1991: CDMA
- 1991: D-AMPS
- 1992: GSM
- 1994: DCS 1800
- 1992: PDC
- 1993: Inmarsat-A
- 1988: Inmarsat-C
- 1992: Inmarsat-B
- 1992: Inmarsat-M
- 2005?: UMTS/IMT-2000

**satellites**
- 1982: Inmarsat-A
- 1988: Inmarsat-C
- 1992: Inmarsat-B
- 1992: Inmarsat-M
- 1998: Iridium

**cordless phones**
- 1980: CT0
- 1984: CT1
- 1987: CT1+
- 1989: CT 2
- 1991: DECT
- 1995/96/97: IEEE 802.11, HIPERLAN
- 2005?: MBS, WATM

**wireless LAN**
- 199x: proprietary
- 1995/96/97: IEEE 802.11, HIPERLAN
- 2005?: MBS, WATM

*analog vs. digital* [J. Schiller]
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.
Mobile phones saturation

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

[chart showing mobile phone saturation from 1999 to 2003]
Internet vs. Mobile phones

- **W. Europe**: 62% Internet, 27% M density
- **USA**: 57% Internet, 28% M density
- **Japan**: 39% Internet, 46% M density
- **China**: 2% Internet, 7% M density
- **ROW**: 2% Internet, 2% M density
- **World**: 7% Internet, 12% M density
Simple reference model

Application
Transport
Network
Data Link
Physical

Network
Data Link
Physical

Network
Data Link
Physical

Application
Transport
Network
Data Link
Physical

Radio
Medium

[Tanenbaum/Schiller]
## Course overview: Networking Bottom – Up Approach

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<th>Layer</th>
<th>Topics</th>
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<tr>
<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>Physical layer</td>
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<td>frequency</td>
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Course Overview: Acronyms
Course overview: A large spectrum

Systems

- WAP
- WML and WMLscript
- Bluetooth
- GSM

How does my wireless LAN card work?

Theory

- How do I route in a mobile ad-hoc network?
- Satellites
- Orthogonal codes
- Optimal Frequency Allocation
- How can we access a shared channel?

Orthogonal codes

$$(a + b)^2 = a^2 + 2ab + b^2$$
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
- Physical and Link Layer
- Media Access Control
- Local Area Networks
- Ad-Hoc Networks
- Ad-Hoc Networks 2
- Mobile IP and TCP
- Other Wireless Media Forms
- Telephony Networks
- Mobile Internet: WAP
- Mobile Applications
- Conclusion

Hard- and Software Tests
"Hello World"
Theory: Codes/MAC
Neighbor Detection / Chat
[Auffahrt]
Multihop Routing
Multihop Routing 2
Multihop Game
Multihop Game 2
Theory: T.b.a.
WAP Design
WAP Implementation
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 Stojmenovic – *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)