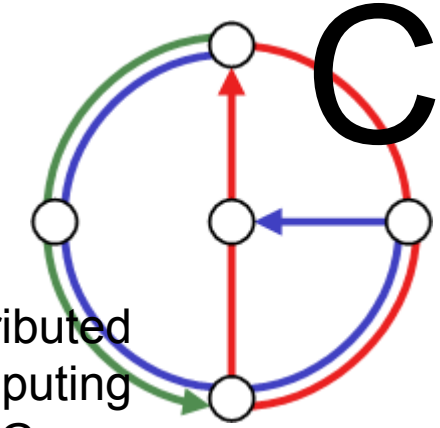
MOBILE COMPUTING

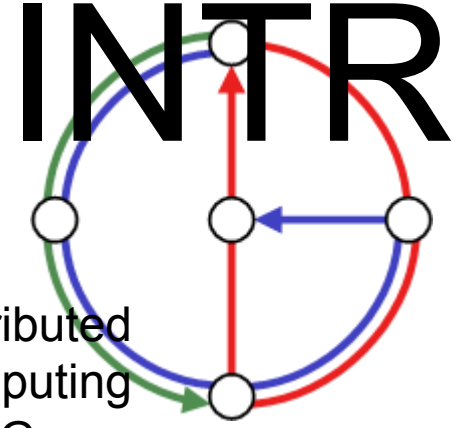


Distributed
Computing
Group

Roger Wattenhofer

Summer 2003

Chapter 1
INTRODUCTION



Distributed
Computing
Group

Mobile Computing

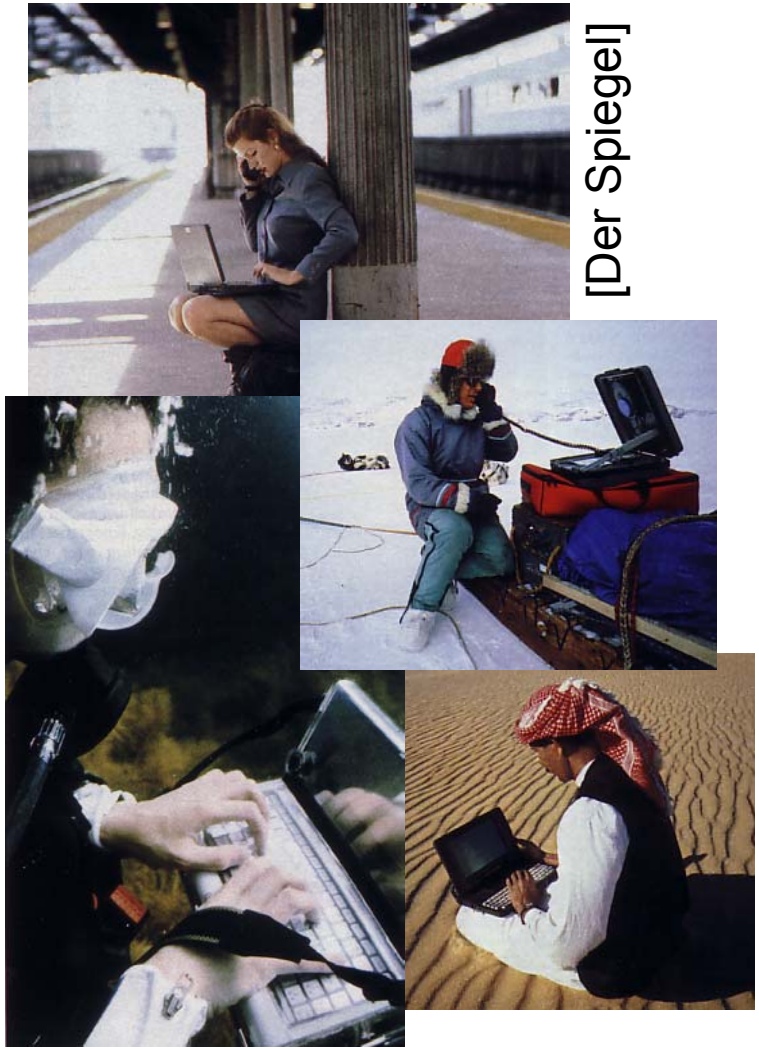
Summer 2003

Overview

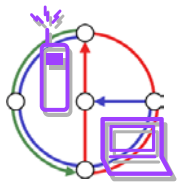
- What is it?
- Who needs it?
- History
- Future

- Course overview
- Organization of exercises
- Literature

- Thanks to J. Schiller for slides

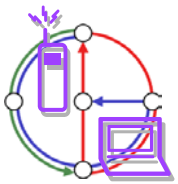


[Der Spiegel]



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?

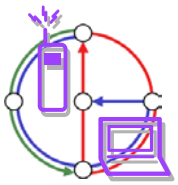


What is *Mobile* Computing?

- 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

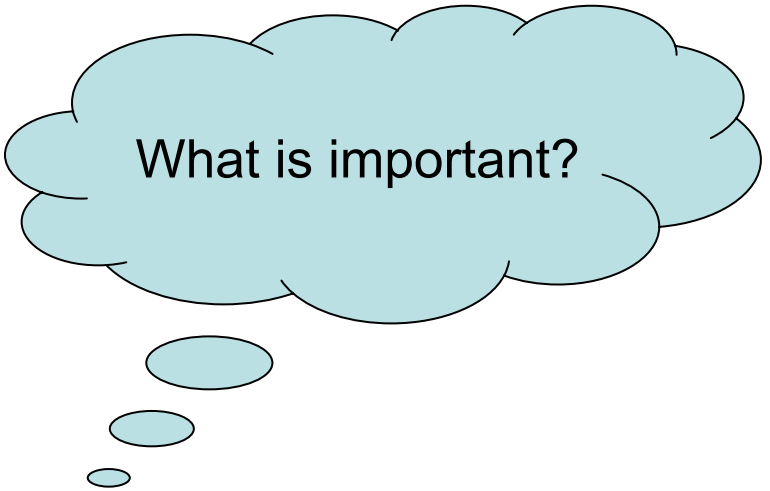
Wireless	Mobile	Example
✗	✗	Stationary computer
✗	✓	Notebook in a hotel
✓	✗	Wireless LANs in historic buildings
✓	✓	Personal Digital Assistant (PDA)

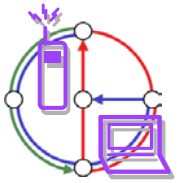
- The demand for mobile communication creates the need for integration of wireless networks and existing fixed networks
  - Local area networks: standardization of IEEE 802.11 or HIPERLAN
  - Wide area networks: GSM and ISDN
  - Internet: Mobile IP extension of the Internet protocol IP



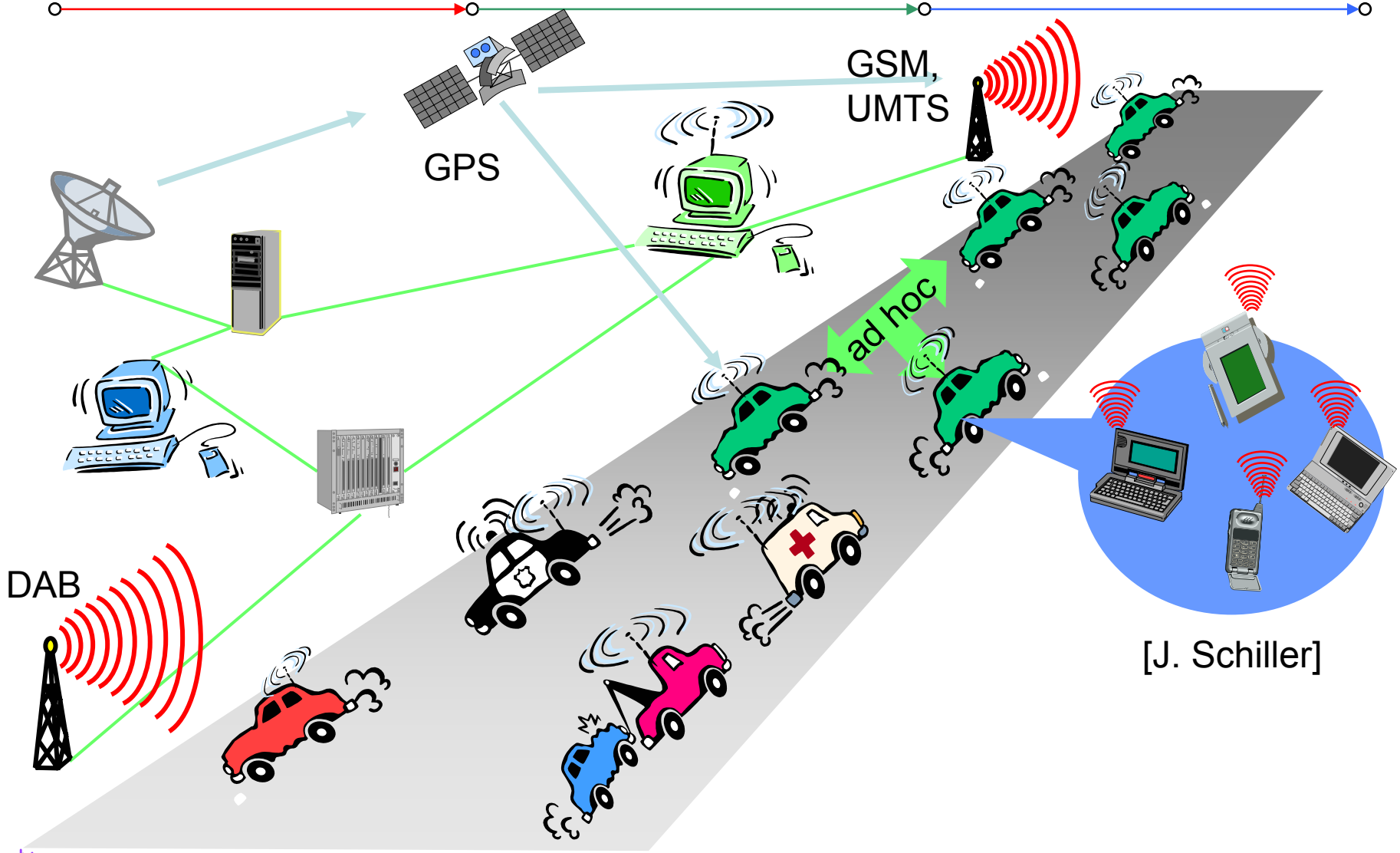
Application Scenarios

- 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

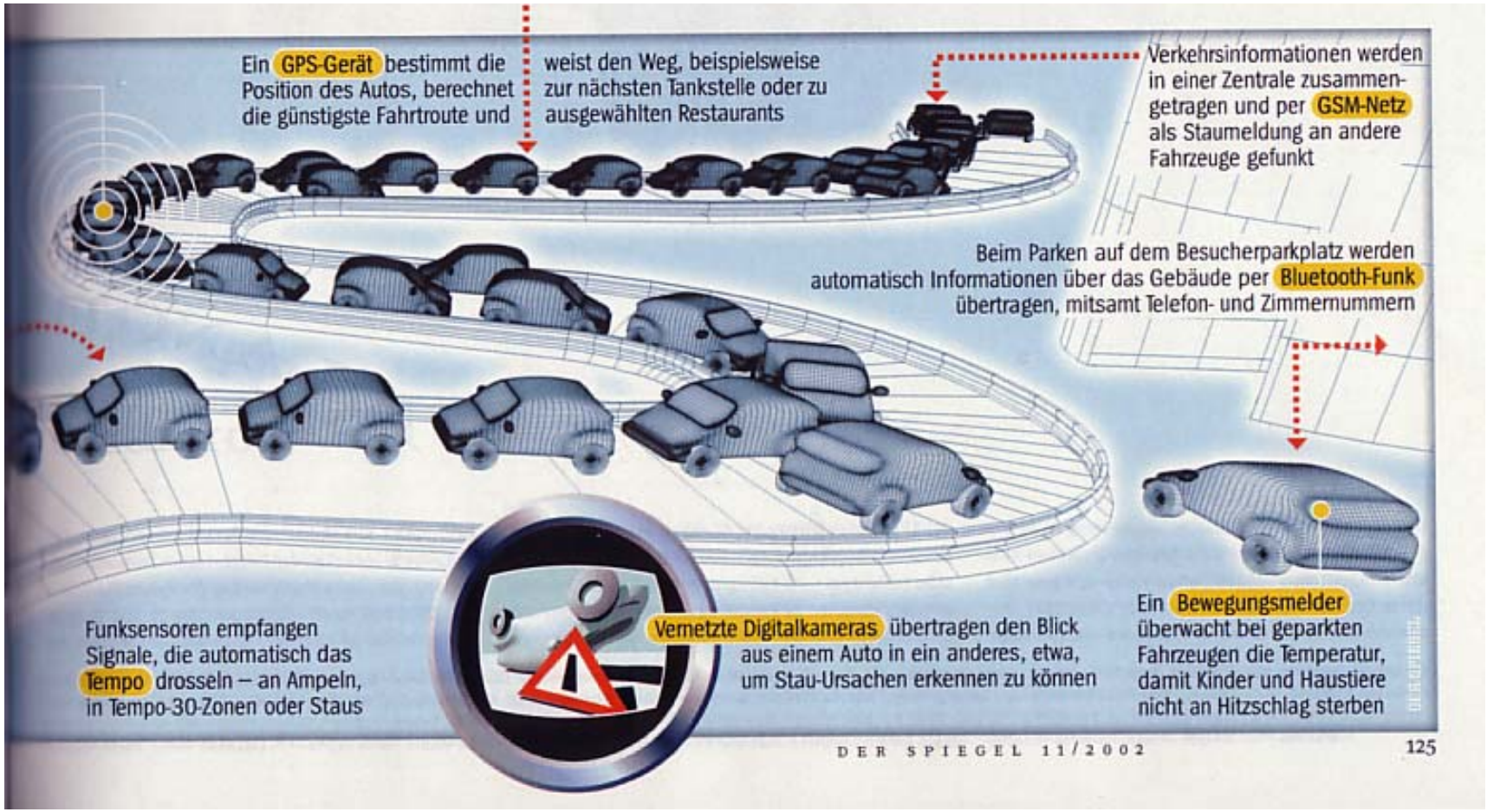




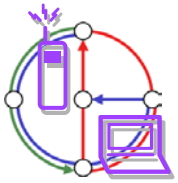
Vehicles



Vehicles 2



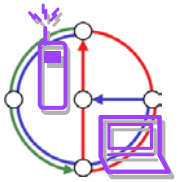
[Der Spiegel]



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?

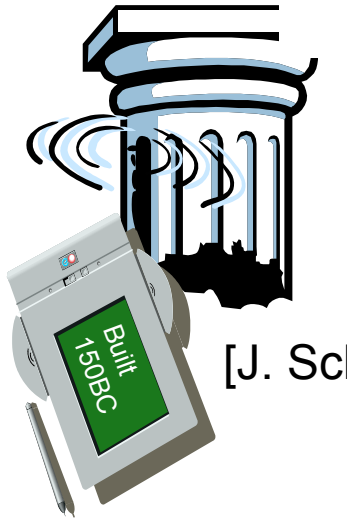
- Does nomadic user need her own hardware?
  - Read/write email on web browser
  - Access data OK too



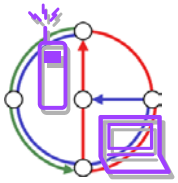
Smart mobile phone

- 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]

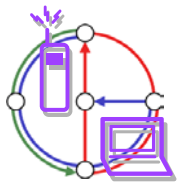


Invisible/ubiquitous/pervasive and wearable computing

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

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

[ABC, Schiele]



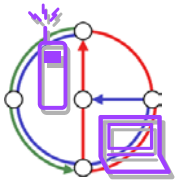
Intelligent Office and Intelligent House

- 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

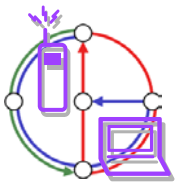
[MS]



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

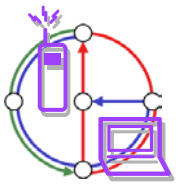
- Ad-Hoc Network



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

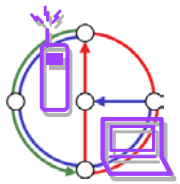
- We really mean *everywhere*!

- Cargo's and yachts
- Journalists
- Scientists
- Travelers

- Sometimes cheaper than infrastructure?

- Commercial flop

[Motorola]

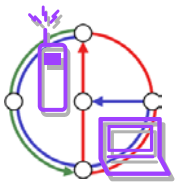


Disaster relief

- 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

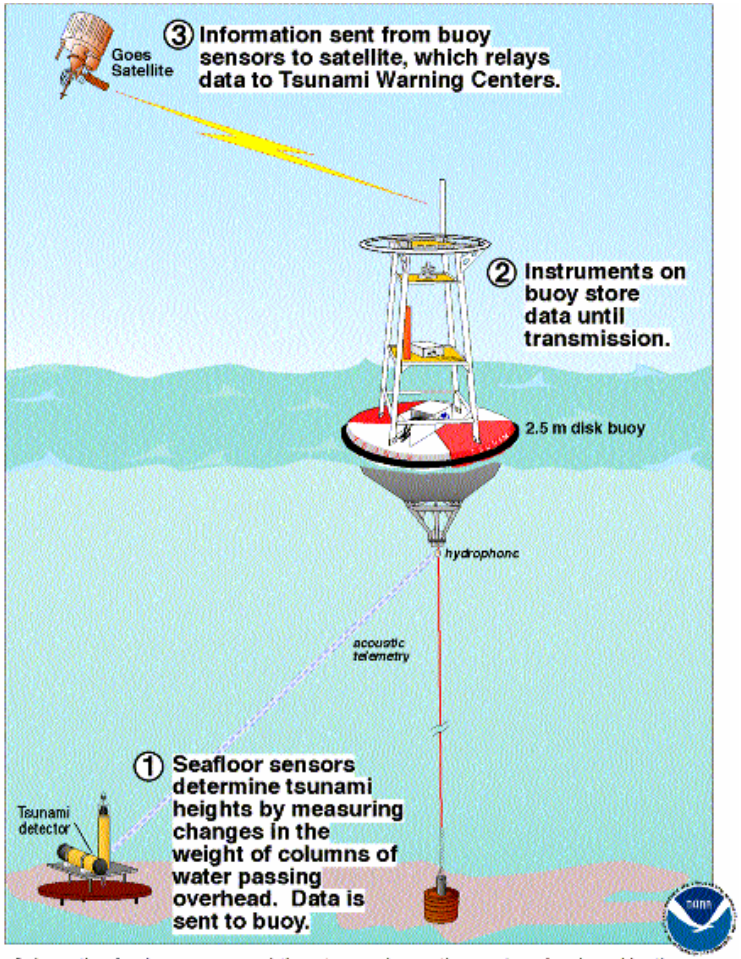
[Red Cross]



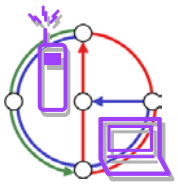
Disaster alarm

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

- Satellite
- Ad-Hoc network



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

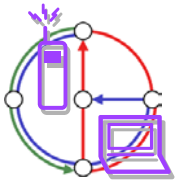


Games

- 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.

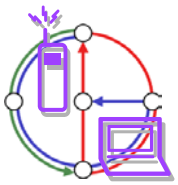
[Cybiko]



Military / Security

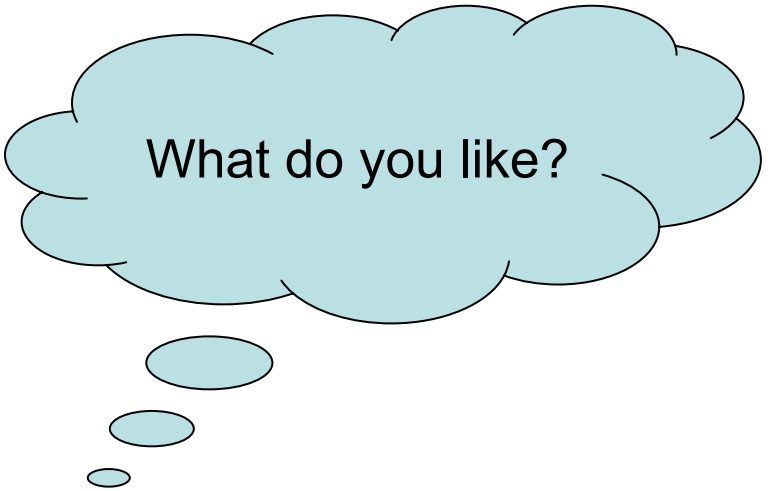
- From a technology standpoint this is similar to disaster relief
- Sensoria says “US army is the best costumer”
- Not (important) in this course

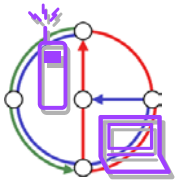
[Der Spiegel]



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?**





Mobile devices

Pager
- receive only
- tiny displays
- simple text messages

Sensors, embedded controllers

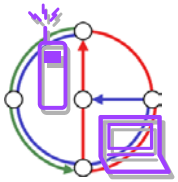
Mobile phone
- voice, data
- simple text display

PDA
- simple graphical displays
- character recognition
- simplified WWW

Palmtop
- tiny keyboard
- simple versions of standard applications

Laptop
- fully functional
- standard applications

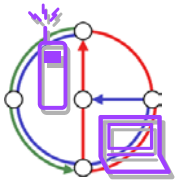
performance and size



What do you have? What would you buy?

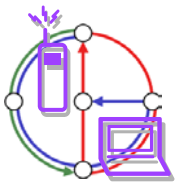
- Laptop (Linux, Mac, Windows?) ✘
- Palmtop (Linux, Mac, Windows?) ✘
- PDA/Organizer (Palm, Pocket PC, other?) ✘
- Mobile phone
- Satellite phone
- Pager
- Wireless LAN Card ✘
- Wireless LAN Base Station (for home networking)
- Ethernet Plug in every room (for home networking)
- Bluetooth
- Proprietary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

for exercises ✘



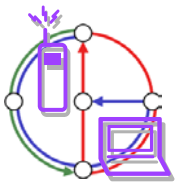
Effects of device portability

- 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)



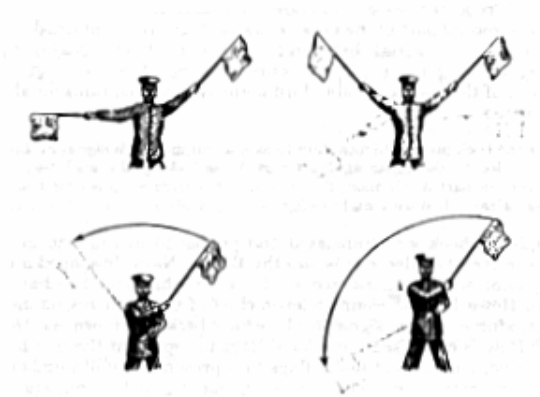
Wireless networks in comparison to fixed networks

- 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

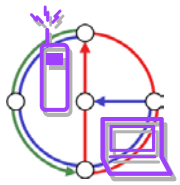


History: Antiquity – 1890

- 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

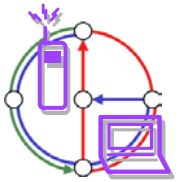


- Electromagnetic waves
  - 1831: Michael Faraday (and Joseph Henry) demonstrate electromagnetic induction
  - 1864: James Maxwell (1831-79): Theory of electromagnetic fields, wave equations
  - 1886: Heinrich Hertz (1857-94): demonstrates with an experiment the wave character of electrical transmission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



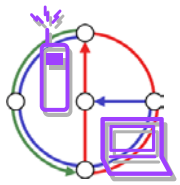
History: 1890 – 1920

- 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



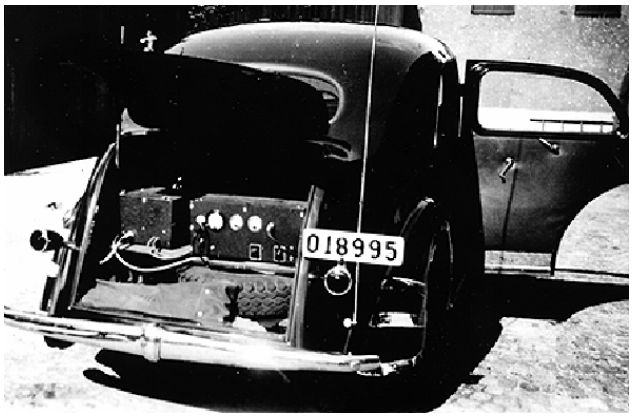
History: 1920 – 1945

- 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)



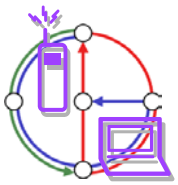
History: 1945 – 1980

- 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



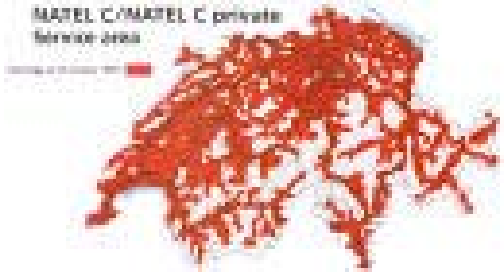
[F.Mattern]

- 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)

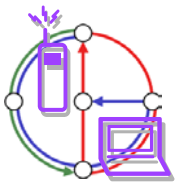


History: 1980 – 1991

- 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

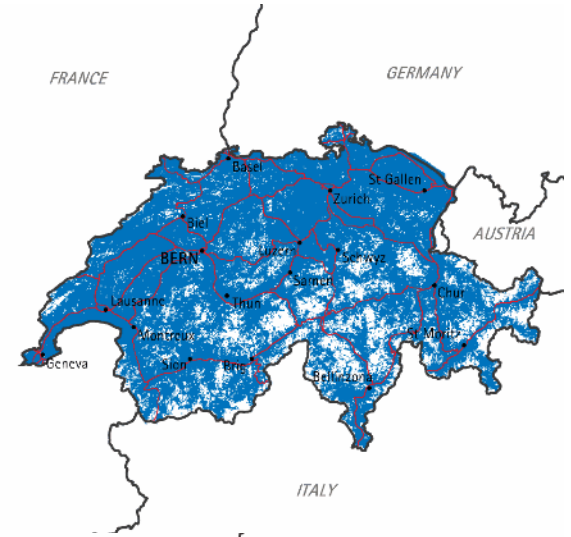


- 1991: DECT
  - Digital European Cordless Telephone. Today: “Enhanced”
  - 1880-1900MHz, ~100-500m range, 120 duplex channels, 1.2Mbit/s data transmission, voice encryption, authentication, up to several 10000 users/km^2, used in more than 40 countries

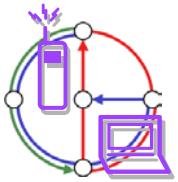


History: 1991 – 1995

- 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, ...

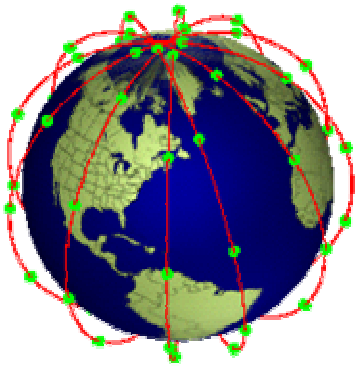


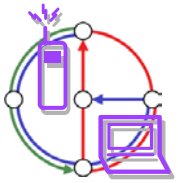
- 1994/5: GSM with 1800MHz
  - smaller cells
  - supported by many countries
  - SMS
  - Multiband phones



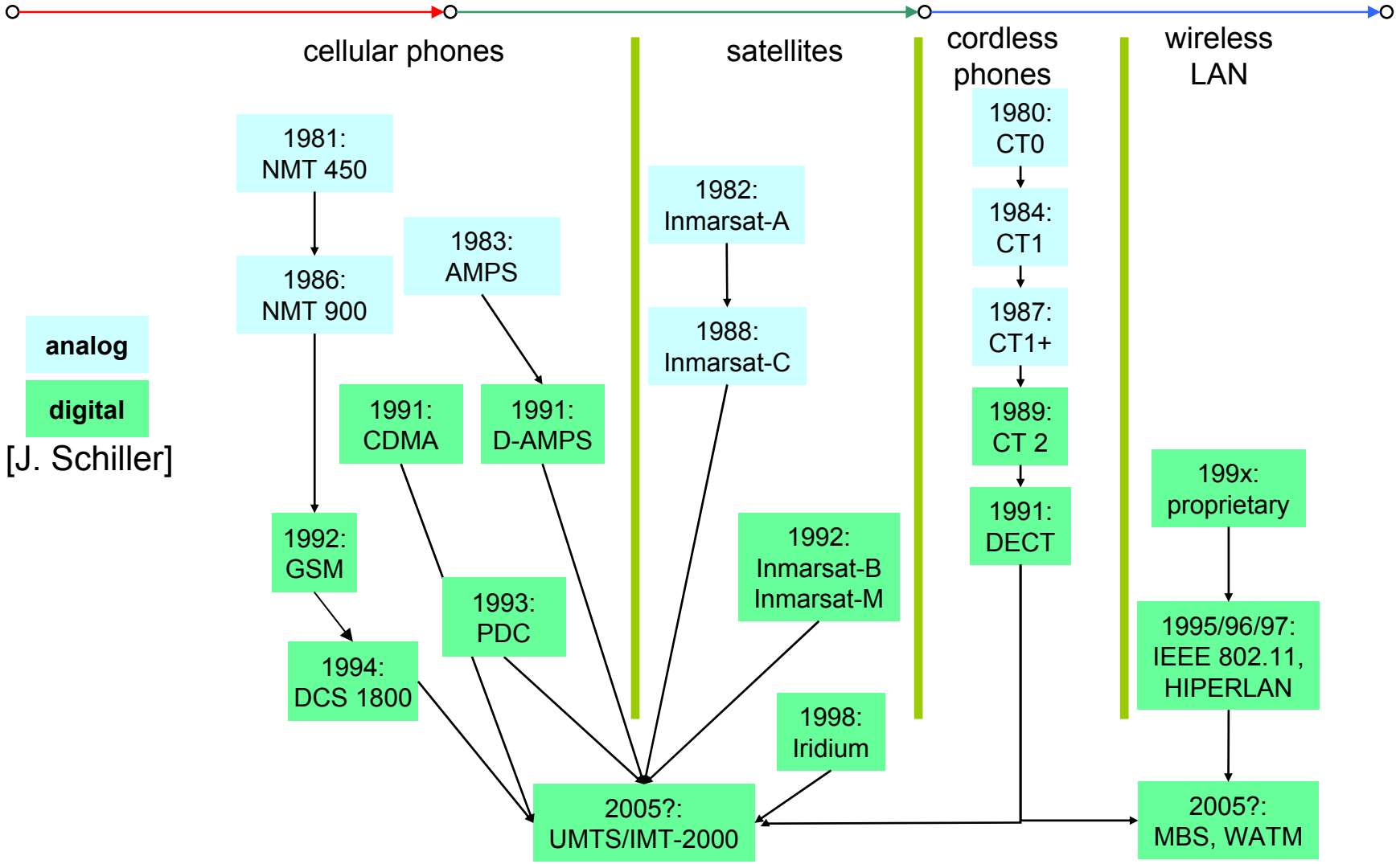
History: 1995 – today

- 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

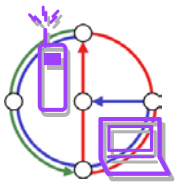




Wireless systems: overview of the development

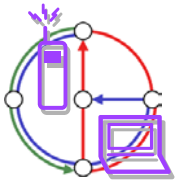


[J. Schiller]



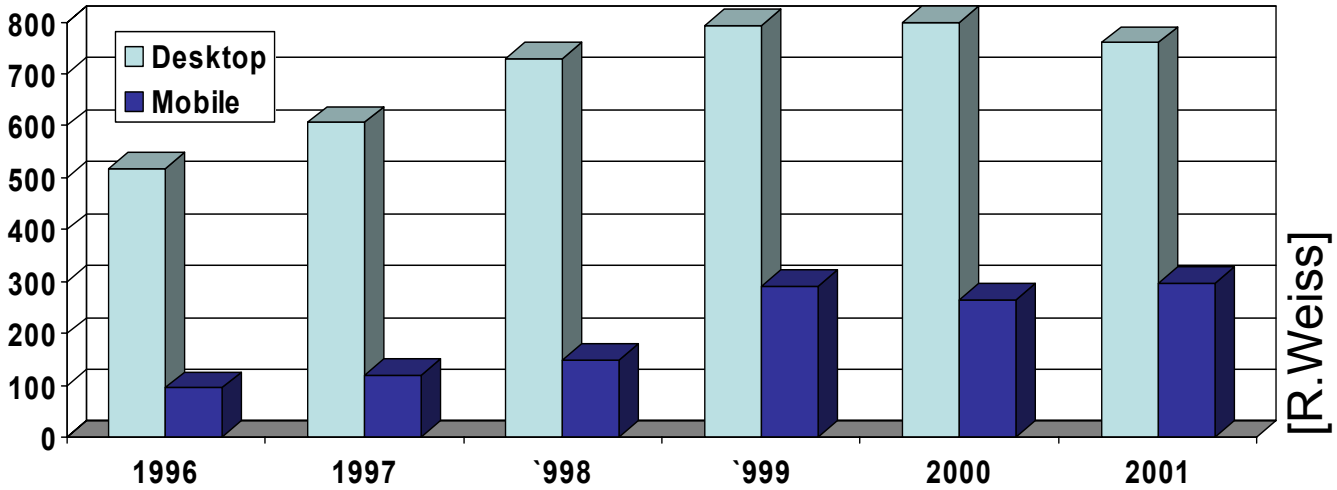
The future: ITU-R - Recommendations for IMT-2000

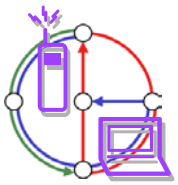
- M.687-2
  - IMT-2000 concepts and goals
- M.816-1
  - framework for services
- M.817
  - IMT-2000 network architectures
- M.818-1
  - satellites in IMT-2000
- M.819-2
  - IMT-2000 for developing countries
- M.1034-1
  - requirements for the radio interface(s)
- M.1035
  - framework for radio interface(s) 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**



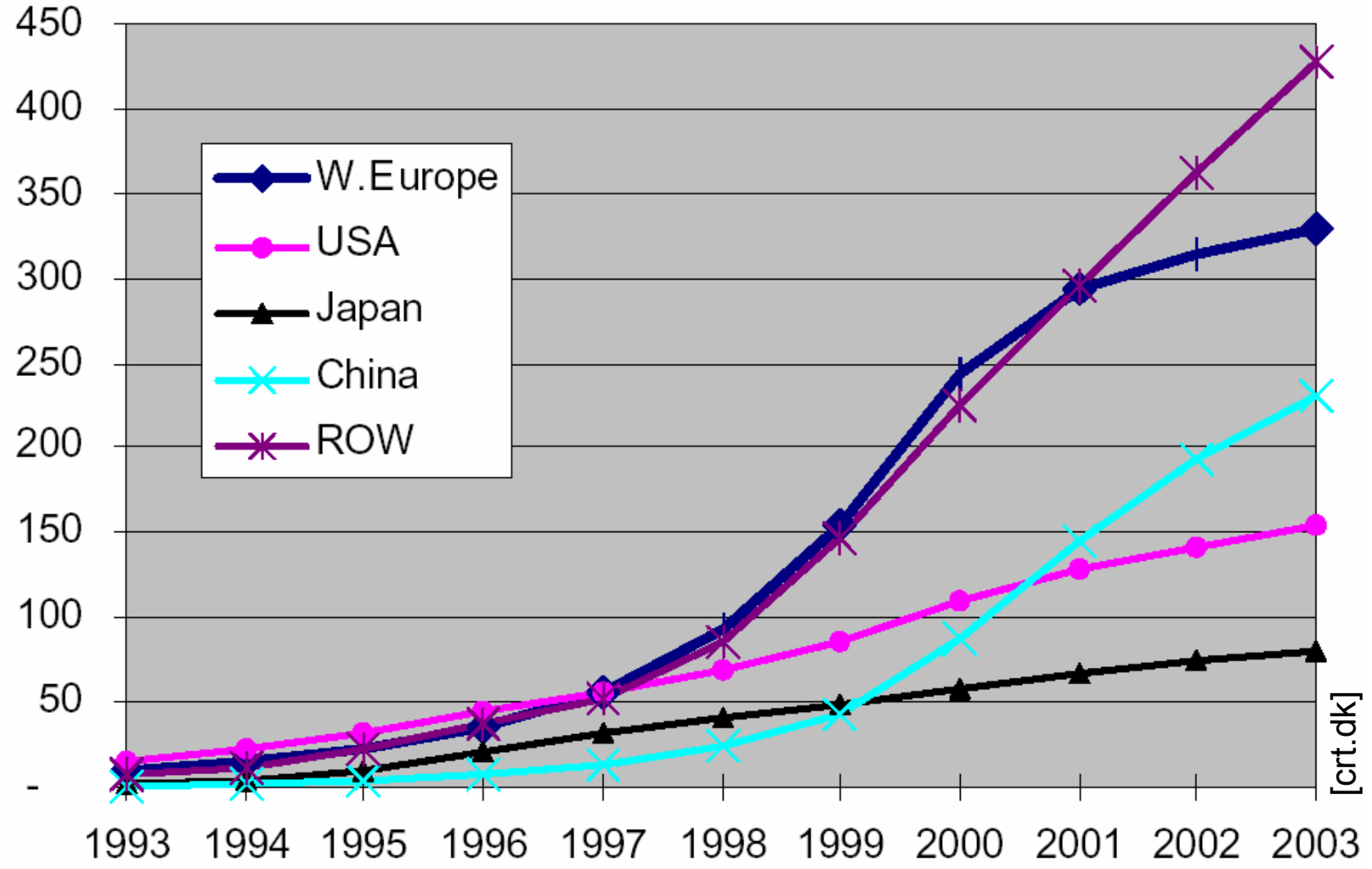
The success story of Mobile “Computing”

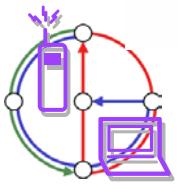
- Mobile Phones
  - Switzerland February 2002: More mobile phones than fixnet phones
  - Worldwide: More mobile phones than Internet connections
  - SMS: “More net profit with SMS than with voice”
- Laptops
  - Switzerland 2001: For the first year less computers sold, but *more* mobile computers; private households buy 18% more laptops than the previous year.



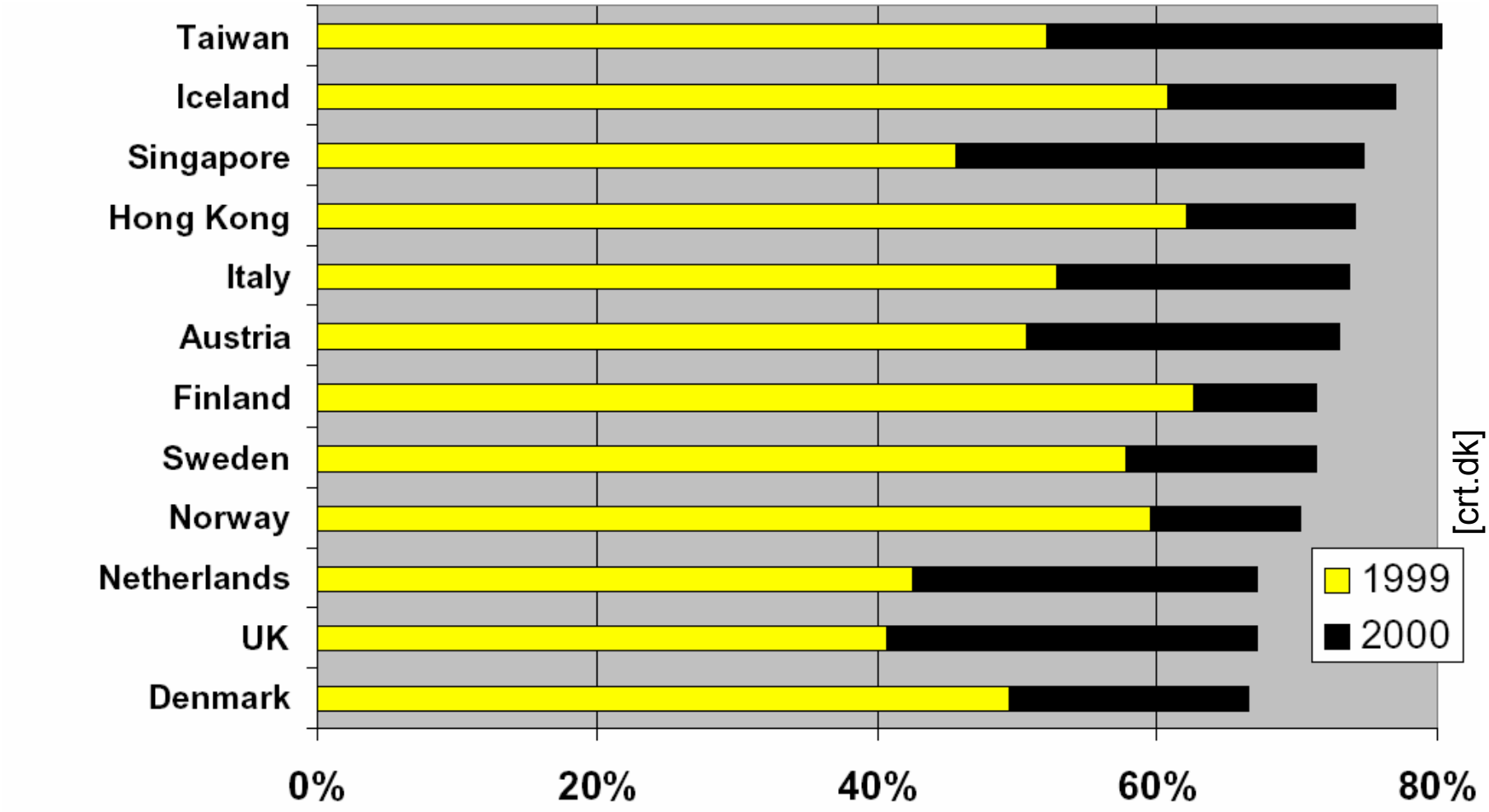


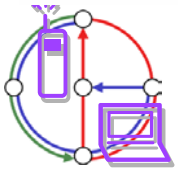
Mobile phones worldwide



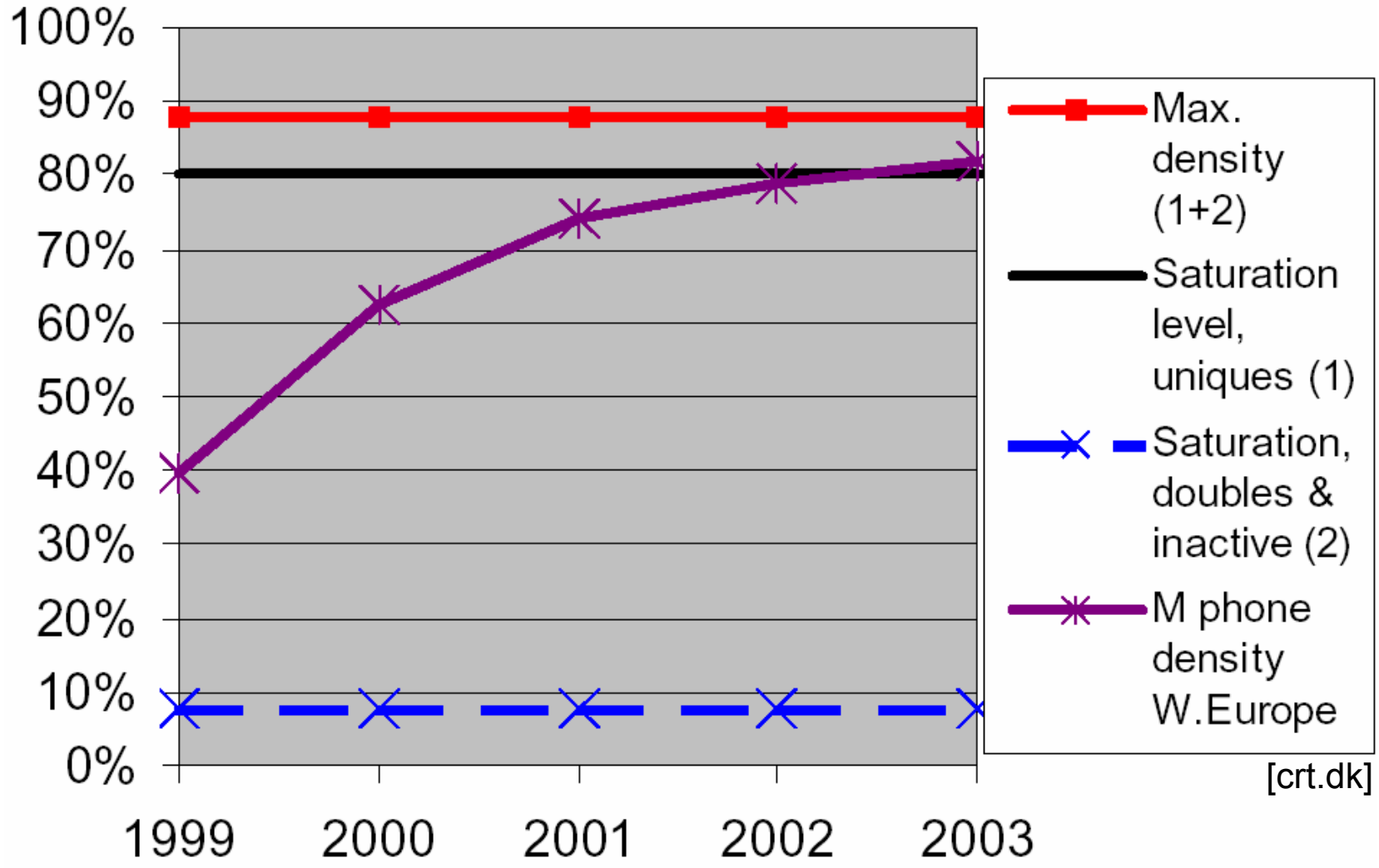


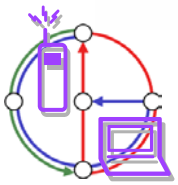
Mobile phones Top 12



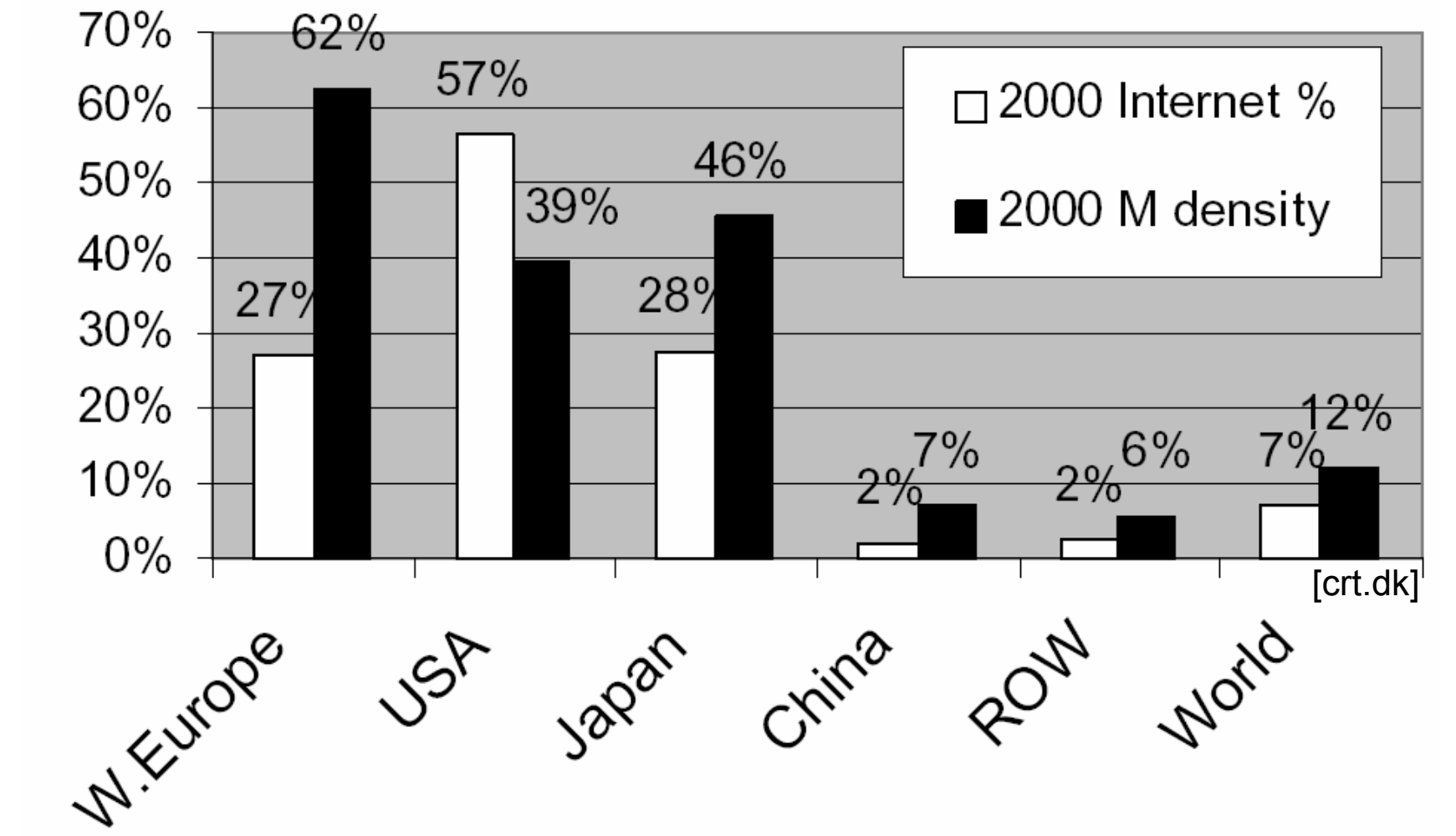


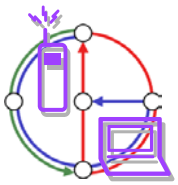
Mobile phones saturation



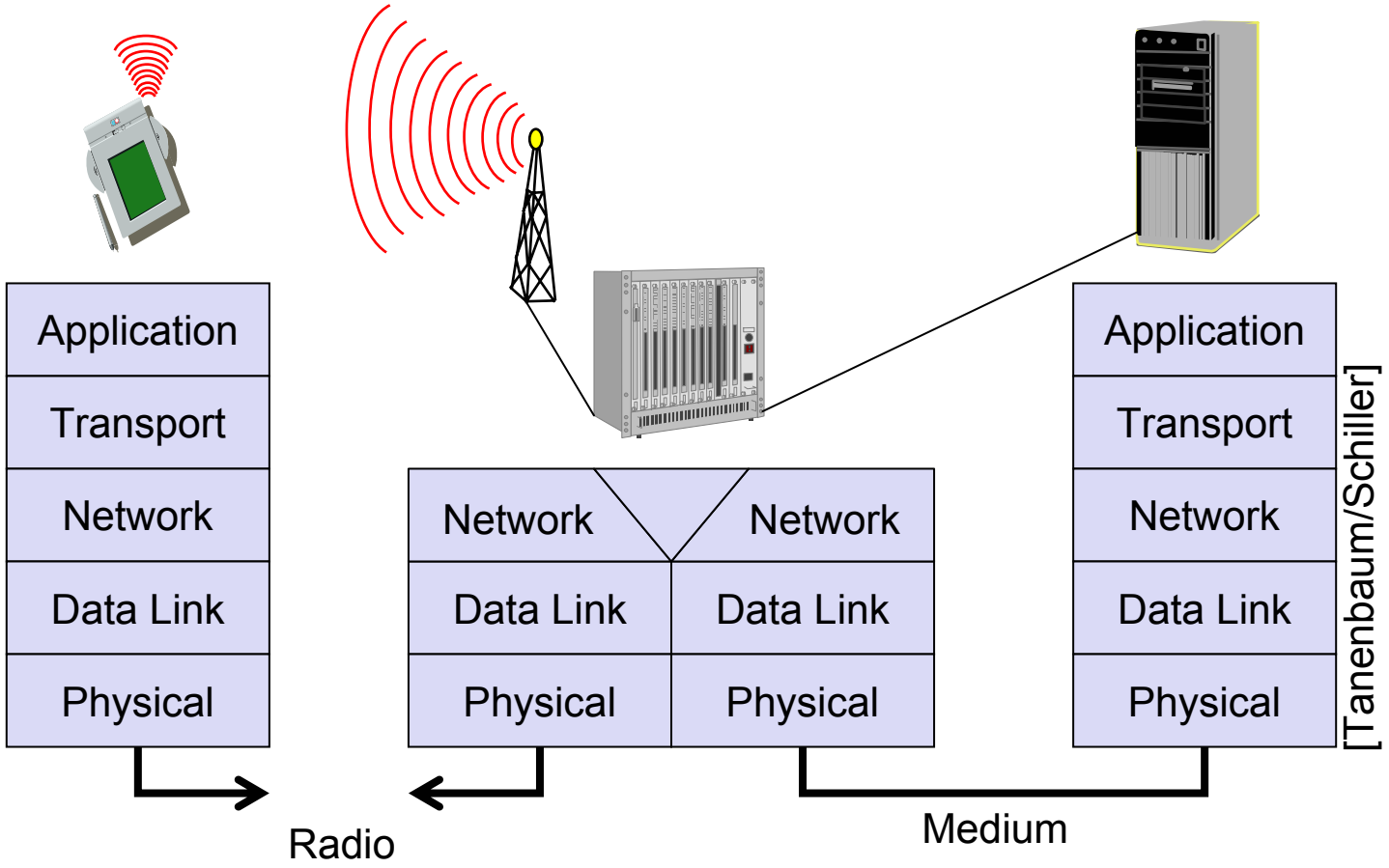


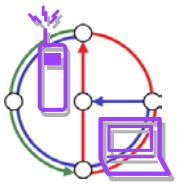
Internet vs. Mobile phones





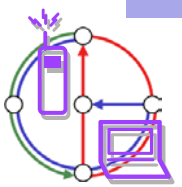
Simple reference model





Course overview: Networking Bottom – Up Approach

- Application layer
  - service location
  - new applications, multimedia
  - adaptive applications
- Transport layer
  - congestion and flow control
  - 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

WATM SC Auth SEC-SAP MF MS CBR NRL DSMA DBPSK 3GPP HC TDMA ML MTC NAV AP M-TCP MBS PTP-CONS SC UD TSF PDF GSM ADSL UNI LEO MSAP PIN FDM PCF SSL BTSM ISMA VLF OTA ADA SACCH DSSS RACH PUK PPM SAMA MM LAPC IOT PAD RTS Res ICO

WSP/B PDC POS CCIR BW UPT BSS MCC FHSS HIPERL AN IFS FIB SNDCP S-SAP WWW MSISD N LAI PDA ATIM CW DVB-T ICMP PSN TTL HEC GIF LAPD CSCW ISO ITU LED CCH CDMA PA ITU-R PDN IEEE IrDA AIDCS CAC HTML CC NDC CCA SNACK IMF JPEG HDTP DPCH HDB HO

TETRA PHY DSDV HA TCH/H ASCII SRES WTA GSN CRC W3C PAL BRAN PSTN MEO MCM CKSN CVSD I-TCP SUMR HSCSD LC RT POTS HDACS TTC ASK FDMA T-TCP VBR-rt LRU BER DIFS BSS PPG HDML EDGE PRMA MSC NA-TDMA BFSK SDTV TCP GMSK MS VPN NAT AMA SCO IMT-DS HF

RLP ACID TINA DQPSK TFI GPRS PACS-UB VHF PT ABR NSA WCAC NTSC EY-NPMA TMSI TDT WDP CPU HMPDU SDU PLW DVB-C HDA CSMA/CA ACL MOC MACA Disassoc TDM LAN DPDCH PLMN DLC QAM EIR AuC HID RM DA PLCP CM SNAP LOS CAC VNDC UHF WCMP L2CAP ARIB MSK ECDH

LF SS7 M-NNI HI T-SAP COA VCC PTP CS PTM WMLScript MTSA BLIRCS RR IMSI DAMA RAND MIB GMM PCH RA NSS LIR SH SDT BSSAP SAAL MATM WTLS TIM FT JCT PDTCH GFSK D-AMPS CDM PCM CSD SW UMTS IV PSK STA RIB EMAS-E MSDU TA RFC CLMS IR NMT

GWL CC XOR TD-CDMA JDC ISI RTT CTS BCA GTP SIM MMF CEPT SCPAS-TP SFD UBR DPCCH SDM PTP-CLNS RL URI PHS TLLI MOT CU UIM PPP AIB MNC WRC IMT-MC WSP WAP ATM-CL LBR PMA TCH/F M-PNNI HCSAP EMAS EIRP CATV DNS V+D FW CSMA DSL FSK PLL AESA CSMA/CD

VC DH HDLC TI RAS MN SDP DVTR CORBA GEO EDTV HMQoS TCH/FS HEO PAD HO-HMPDU SAP SDMA WML EHF HIB FEC FIC TC-HMPDU VDB AID ACT FR PRACH AFS CIF LI PACS RIP Loc AGCH ASA IWF BLIR TR-SAP UDP SCF IMT-FT Cnf ISDN HTTP BPSK TFO ESS RTT TMN

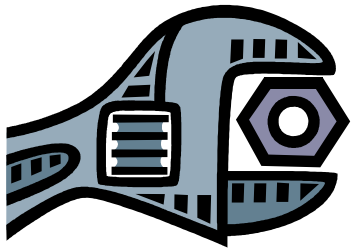
DTIM HBR CD TLS VBR DVD MSIN HCQoS LA DDIB SS PNNI CIDR DTMF MSC EIT IMEI Codec UP ARQ UN ILR WAE IETF CDV Assoc HP DCA MH CDPD GAP LLC BTS LM B-ISDN HLR M-QoS TPC TV WPAN SI RAL GR WP-CDMA AMPS NIT BLI MPEG VHE PCS CCF

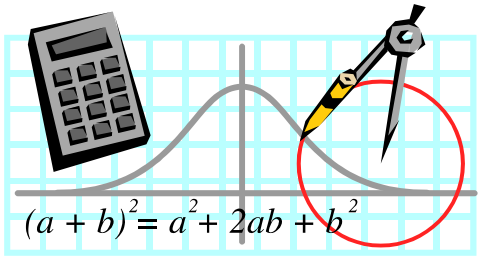
HCPDU USIM TCH/HS DS GPS CGI PLI WIM SDCCH NMAS MCI IMT-TC CPM OFDM TIB ANSI BCCH ASP NFS ITU-T SFN TFTS WMT MHEG ATM NIB RLC WAN SGSN DECT PMD WTAI FCCH FM CAMEL FA COS QoS UE PI TDD SCDMA LMP ARQN DCS VLR SATM VBR-nrt HM ACK SwMI

FACCH DCCH LAPDm AK-HCPDU DT-HCPDU WLAN SHF VAD SIFS WLL RA MSC PSF W-CTRL GP FDD UWC BSSGP BCH MT ID SMRIB UTRAN NNI PIFS GGSN HCSDU IMT OMC AAL WTP DCF SCH FCA PDU IN IMT-SC SA PSPDN GERAN GSM EDGE RAN M-UNI DSR TCH MAC RNS BMP OSS W-CDMA SCPS AMES IP

MSRN SN PDO GMSC SIG CN HDTV AUS T USSD CT SMS DFWMAC DHCP BSC KID ROM ETSI ISM QPSK UTRA GRE TM Req DVB-S FPLMTS CCCH ISL MUL DC COFDM OSI AM DVB RTR SEQN COMS RSS PS PM TOS PC DAB PCS LS RSA RRM CN TE IS XML

Course overview: A large spectrum





Systems

Theory

WAP

WML and WMLscript

Bluetooth

GSM

How does my wireless LAN card work?

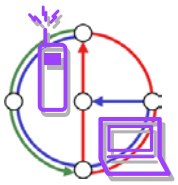
Satellites

How do I route in a mobile ad-hoc network?

Optimal Frequency Allocation

Orthogonal codes

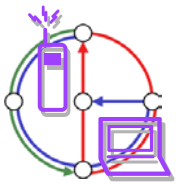
How can we access a shared channel?



Course overview: Hands-On Exercises

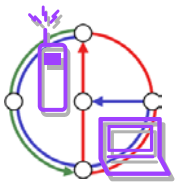
- We build a wireless LAN based ad-hoc network
  - We start with the “hello world” equivalent
  - Neighbor detection
  - Chat application
  - Multihop routing
  - Multihop chat
  - Multihop game

- Supported by
  - paper exercises
  - WAP exercises



Course overview: Lectures and *Exercises*

Introduction	
Physical and Link Layer	*Hard- and Software Tests*
Media Access Control	*"Hello World"*
[Ostern]	*Theory: Codes/MAC*
Wireless LAN	*Neighbor Detection*
Ad-Hoc Networks	*Instant Messenger*
Geometric Routing	*Topology Detection*
Clustering	*Multihop Routing 1*
Mobile IP and TCP	*Multihop Routing 2*
GSM	*Multihop Game*
[Pfingsten]	*Theory: Cells*
File Systems & Mobile Objects	*Theory: T.b.a.*
Mobile Web	*WAP*

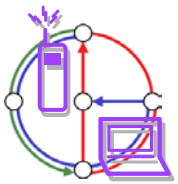


Course specialties

- We are clueless about the number of students
- We are clueless about the availability of systems

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

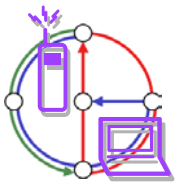
- http://distcomp.ethz.ch/mobicomp



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)