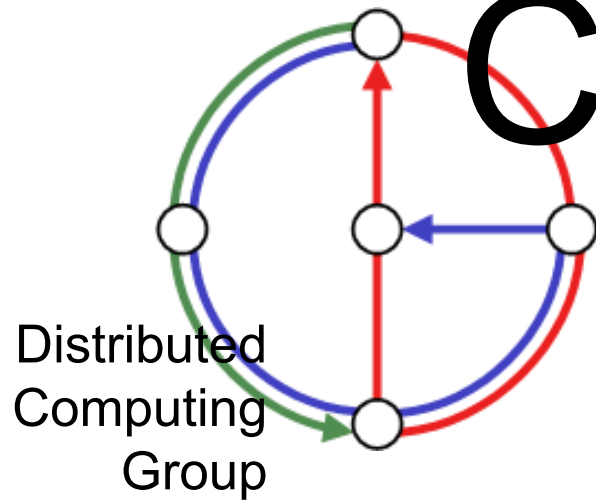


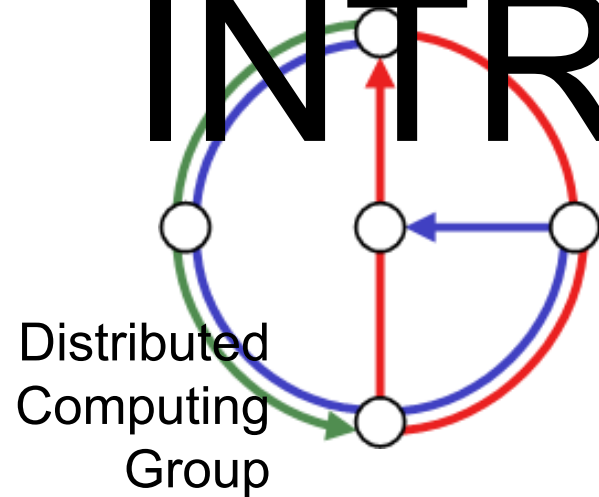
MOBILE COMPUTING



Roger Wattenhofer
Summer 2002

Chapter 1

INTRODUCTION



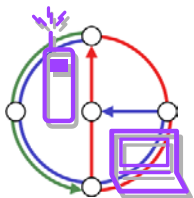
Mobile Computing
Summer 2002

Overview

- What is it?
 - Who needs it?
 - History
 - Future
-
- Course overview
 - Organization of exercises
 - Literature
-
- Thanks to J. Schiller for slides



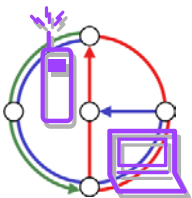
[Der Spiegel]



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?

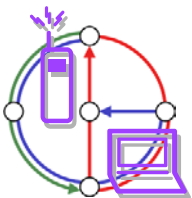


What is *Mobile* Computing?



- 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

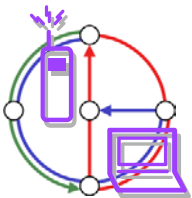
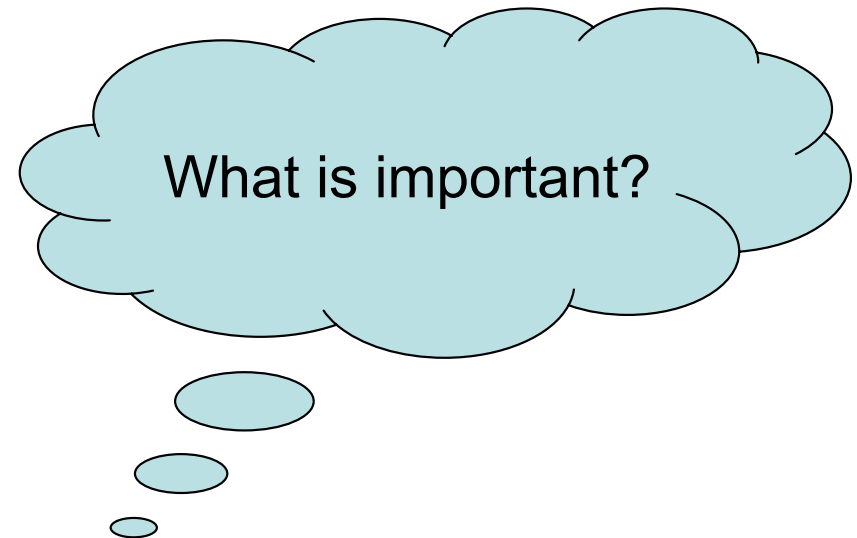
<div style="color: red; font-size: 2em;">×</div> <div style="color: red; font-size: 2em;">×</div> <div style="color: green; font-size: 2em;">✓</div> <div style="color: green; font-size: 2em;">✓</div>	<div style="color: red; font-size: 2em;">×</div> <div style="color: green; font-size: 2em;">✓</div> <div style="color: red; font-size: 2em;">×</div> <div style="color: green; font-size: 2em;">✓</div>	<p>Stationary computer</p> <p>Notebook in a hotel</p> <p>Wireless LANs in historic buildings</p> <p>Personal Digital Assistant (PDA)</p>
---	---	--
- 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



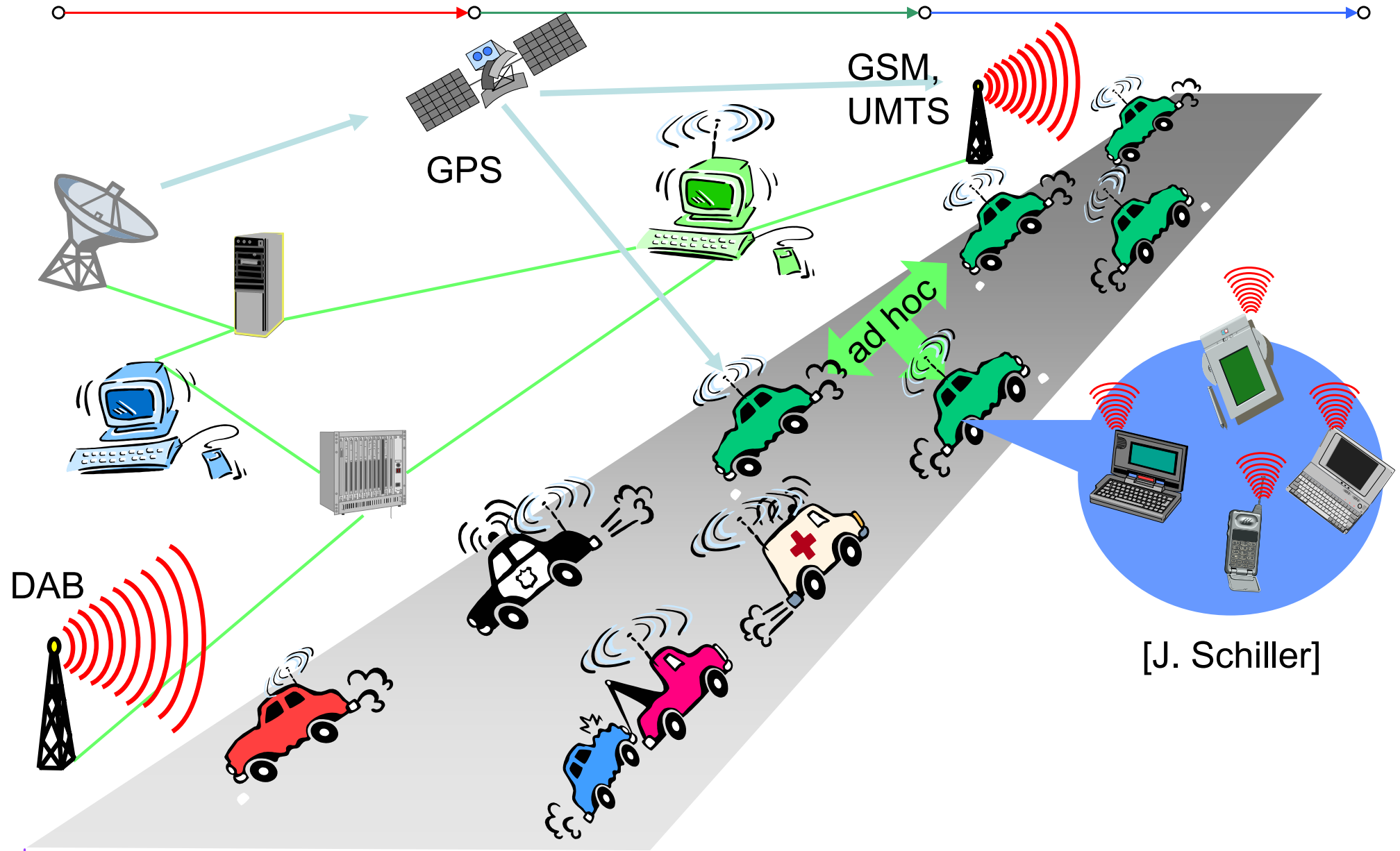
Application Scenarios



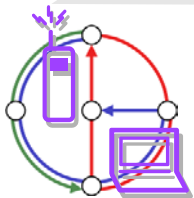
- Vehicles
- Nomadic user
- Smart mobile phone
- Invisible computing
- Wearable computing
- Intelligent house or office
- Meeting room/conference
- Taxi/Police/Fire squad fleet
- Service worker
- Lonely wolf
- Disaster relief and Disaster alarm
- Games
- Military / Security



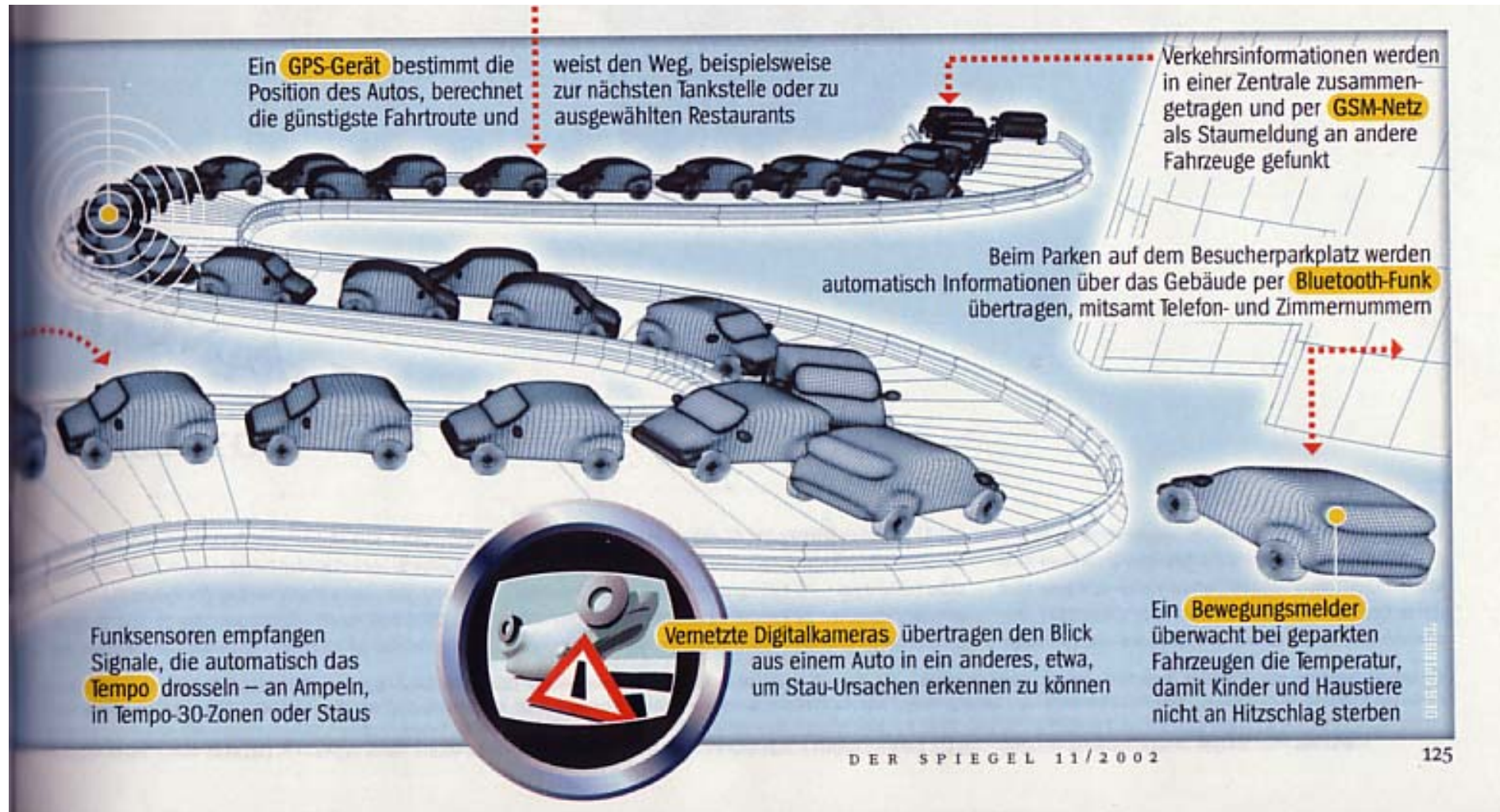
Vehicles



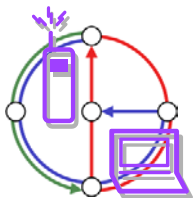
[J. Schiller]



Vehicles 2



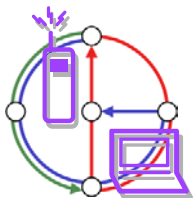
[Der Spiegel]



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



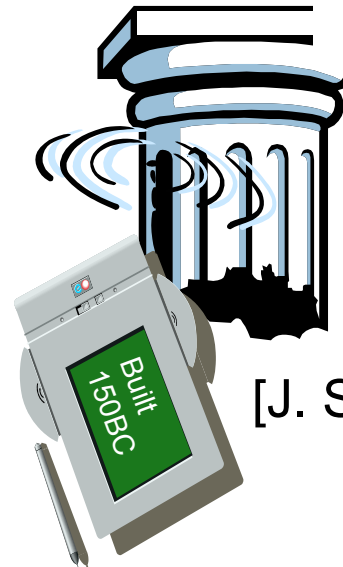
Smart mobile phone



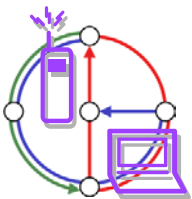
- Mobile phones get smarter
- Converge with PDA?
- Voice calls, video calls (really?)
- Email or instant messaging
- Play games
- Up-to-date localized information
 - Map
 - Pull: Find the next Pizzeria
 - Push: “Hey, we have great Pizza!”
- Stock/weather/sports info
- Ticketing
- Trade stock
- etc.



[Nokia]



[J. Schiller]



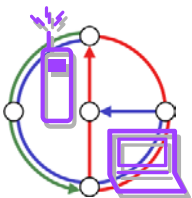
Invisible/ubiquitous/pervasive and wearable computing



- Tiny embedded “computers”
- Everywhere
- Example: Microsoft’s Doll
- I refer to my colleagues Friedemann Mattern and Bernt Schiele and their courses



[ABC, Schiele]



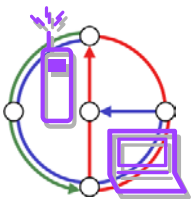
Intelligent Office and Intelligent House



- 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



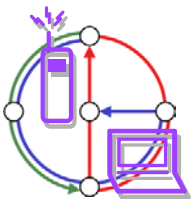
[MS]



Meeting room or Conference



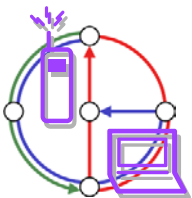
- Share data instantly
- Send a message to someone else in the room
- Secretly vote on controversial issue
- Find person with similar interests
- Broadcast last minute changes
- Ad-Hoc Network



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



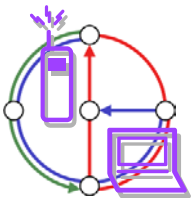
Lonely wolf



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



[Motorola]

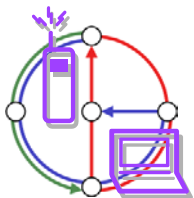


Disaster relief

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

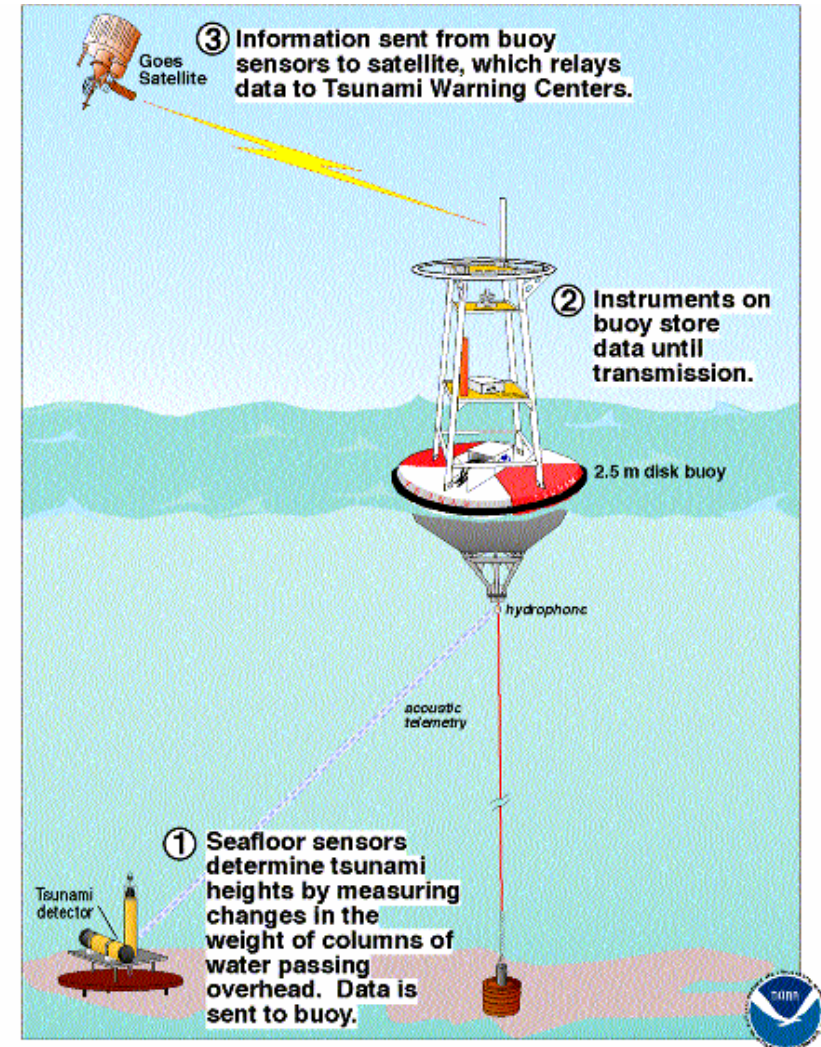


[Red Cross]

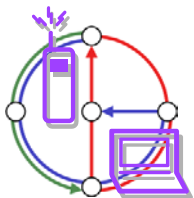


Disaster alarm

- 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).

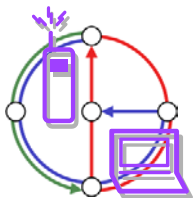


Games

- 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]

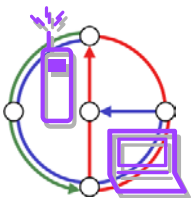


Military / Security

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

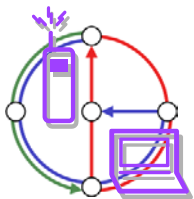
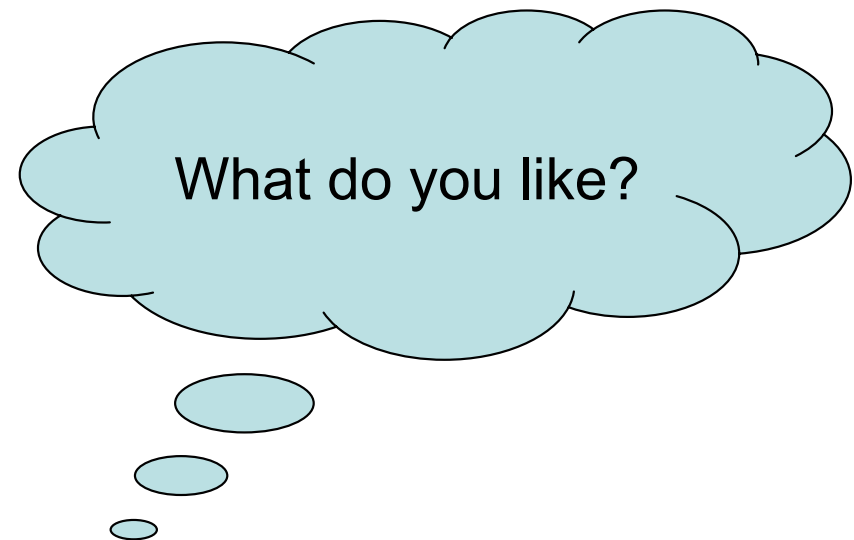


[Der Spiegel]



Application Scenarios: Discussion

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

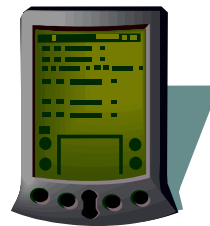


Mobile phone

- voice, data
- simple text display

PDA

- simple graphical displays
- character recognition
- simplified WWW

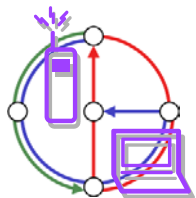


Palmtop

- tiny keyboard
- simple versions of standard applications

Laptop

- fully functional
- standard applications

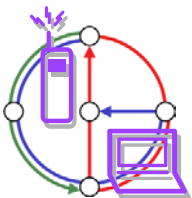


What do you have? What would you buy?



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

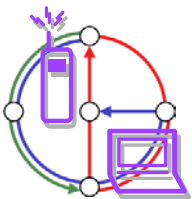
for exercises x



Effects of device portability

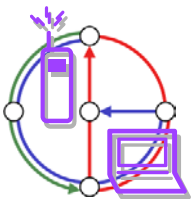


- Energy consumption
 - there is no Moore's law for batteries or solar cells
 - limited computing power, low quality displays, small disks
 - Limited memory (no moving parts)
 - Radio transmission has a high energy consumption
 - CPU: power consumption $\sim CV^2f$
 - C: total capacitance, reduced by 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)



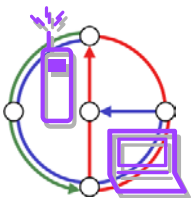
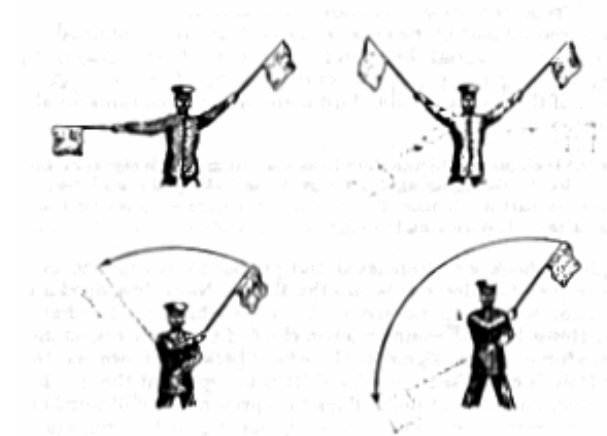
Wireless networks in comparison to fixed networks

- 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



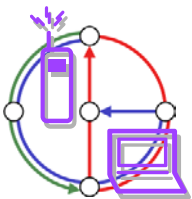
History: Antiquity – 1890

- 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



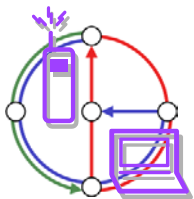
History: 1890 – 1920

- 1895: Guglielmo Marconi (1874 – 1937)
 - first demonstration of wireless telegraphy (digital!)
 - long wave transmission, high transmission power necessary ($> 200\text{kW}$)
 - 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

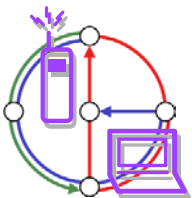


- 1958: German A-Netz
 - Analog, 160MHz, connection setup only from mobile station, no handover, 80% coverage, 16kg, 15k Marks
 - 1971: 11000 customers
 - Compare with PTT (Swisscom) NATEL: 1978 – 1995, maximum capacity 4000, which was reached 1980



[F.Mattern]

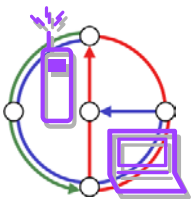
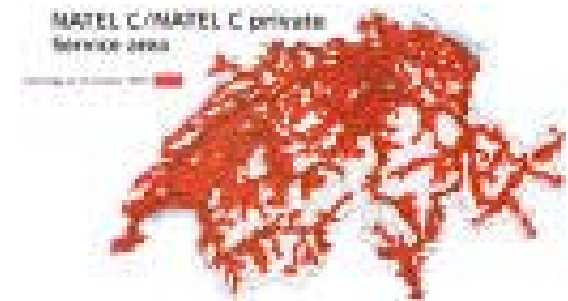
- 1972: German B-Netz
 - Analog, 160MHz, connection setup from the fixed network too (but location of the mobile station has to be known)
 - available also in A, NL and LUX, 1979 13000 customer in D
 - PTT NATEL B: 1984 – 1997, maximum capacity 9000
- 1979: NMT Nordic Mobile Telephone System
 - 450MHz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



History: 1980 – 1991

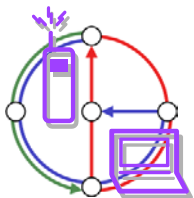
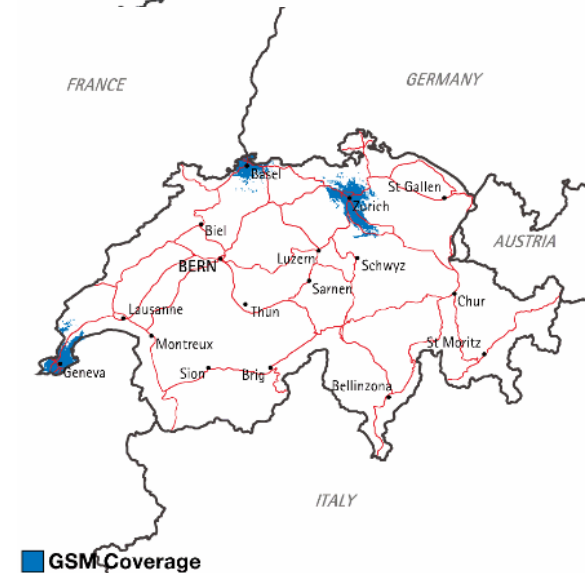
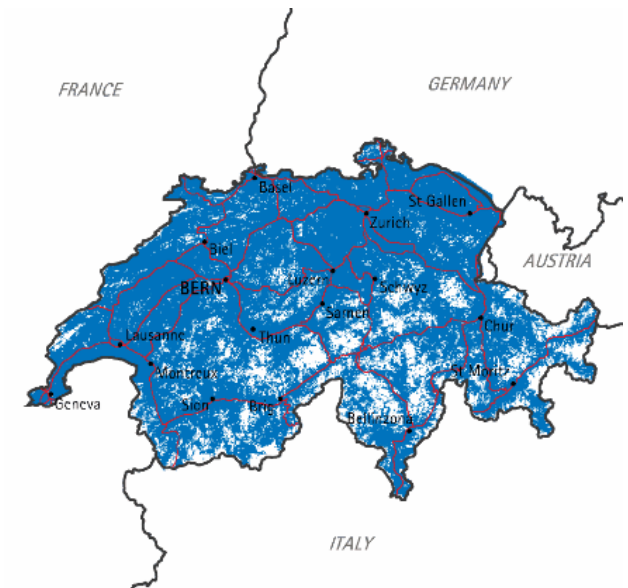


- 1982: Start of GSM-specification (Groupe spéciale mobile)
 - goal: pan-European *digital* mobile phone system with *roaming*
- 1984: CT-1 standard for cordless telephones
- 1986: German C-Netz
 - analog voice transmission, 450MHz, hand-over possible, digital signaling, automatic location of mobile 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/km², used in more than 40 countries



History: 1991 – 1995

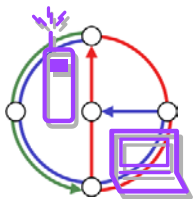
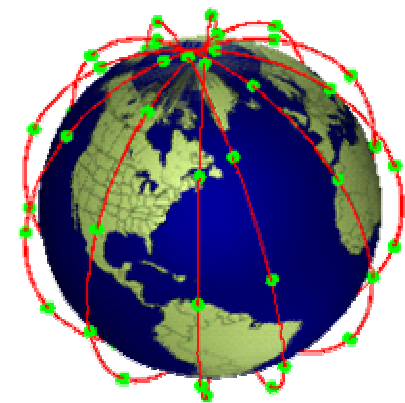
- 1992/3: Start of GSM “D-Netz”/“NATEL D”
 - 900MHz, 124 channels
 - automatic location, hand-over, cellular
 - roaming in Europe
 - now worldwide in more than 130 countries
 - services: data with 9.6kbit/s, FAX, voice, ...
- 1994/5: GSM with 1800MHz
 - smaller cells
 - supported by many countries
 - SMS
 - Multiband phones



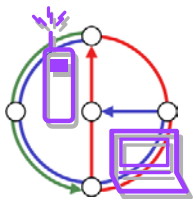
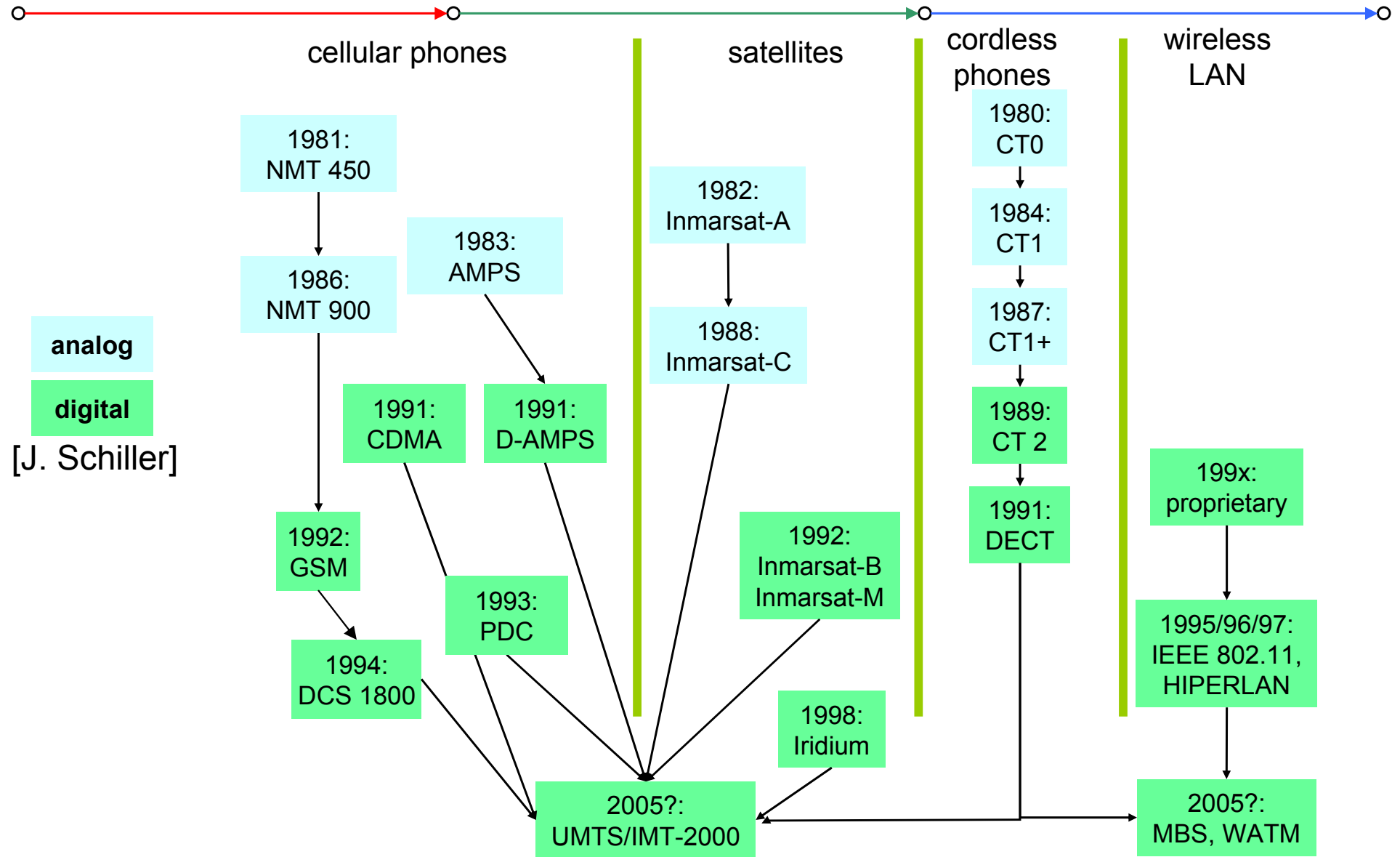
History: 1995 – today



- 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



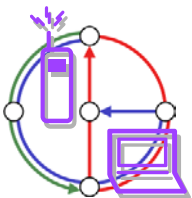
Wireless systems: overview of the development



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

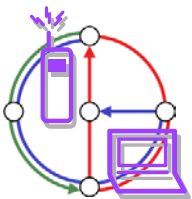
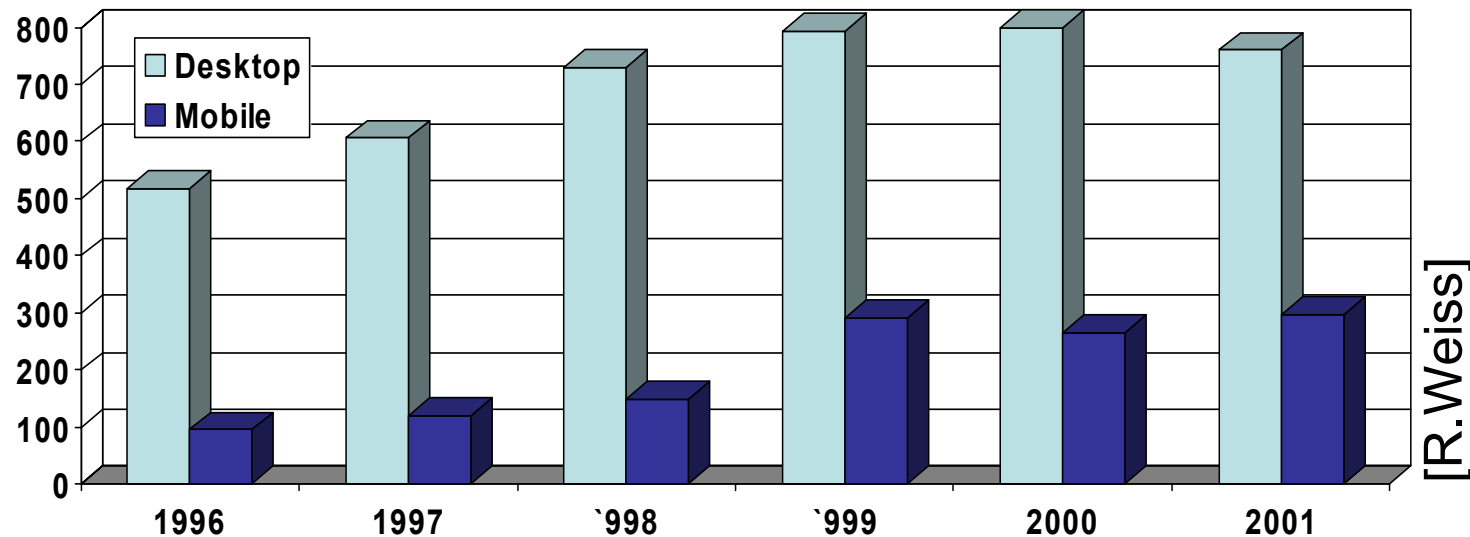


- M.687-2
 - IMT-2000 concepts and goals
- M.816-1
 - framework for services
- M.817
 - IMT-2000 network architectures
- M.818-1
 - satellites in IMT-2000
- M.819-2
 - IMT-2000 for developing countries
- M.1034-1
 - requirements for the radio interface(s)
- M.1035
 - framework for radio interface(s)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

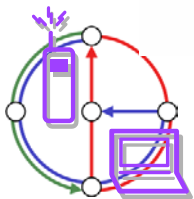
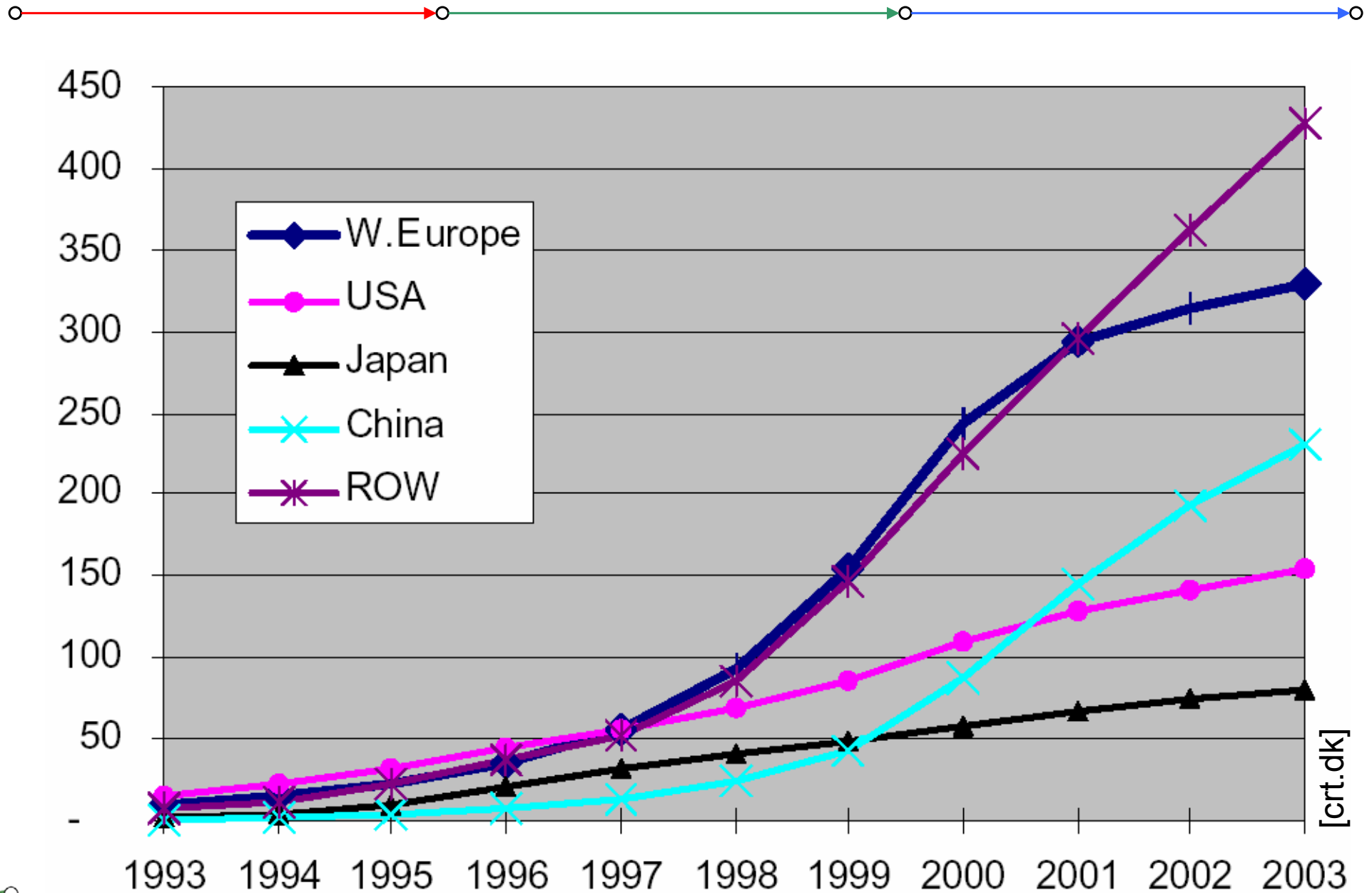


The success story of Mobile “Computing”

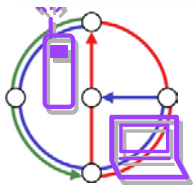
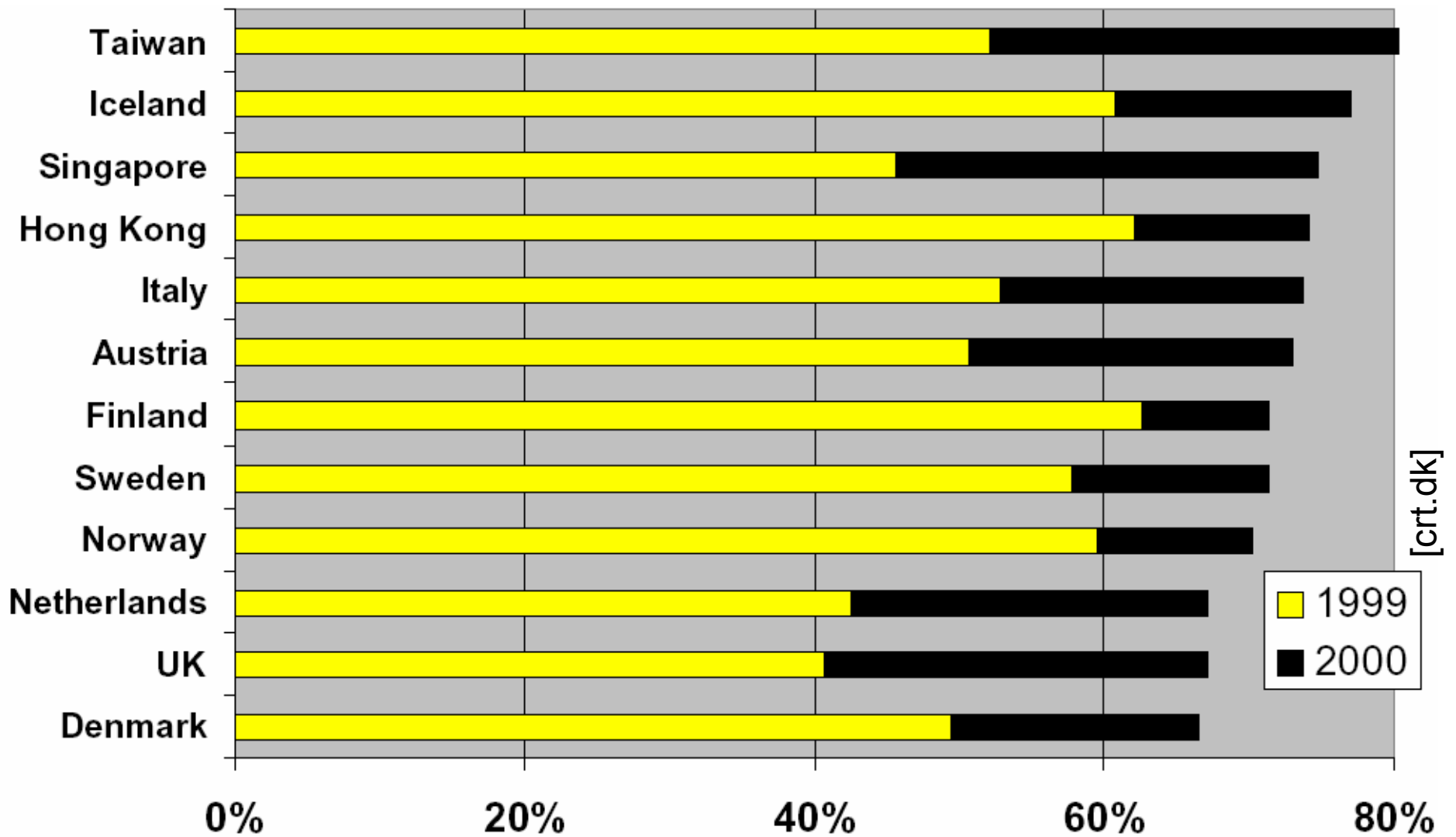
- Mobile Phones
 - Switzerland February 2002: More mobile phones than fixnet phones
 - Worldwide: More mobile phones than Internet connections
 - SMS: “More net profit with SMS than with voice”
- Laptops
 - Switzerland 2001: For the first year less computers sold, but *more* mobile computers; private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



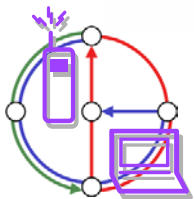
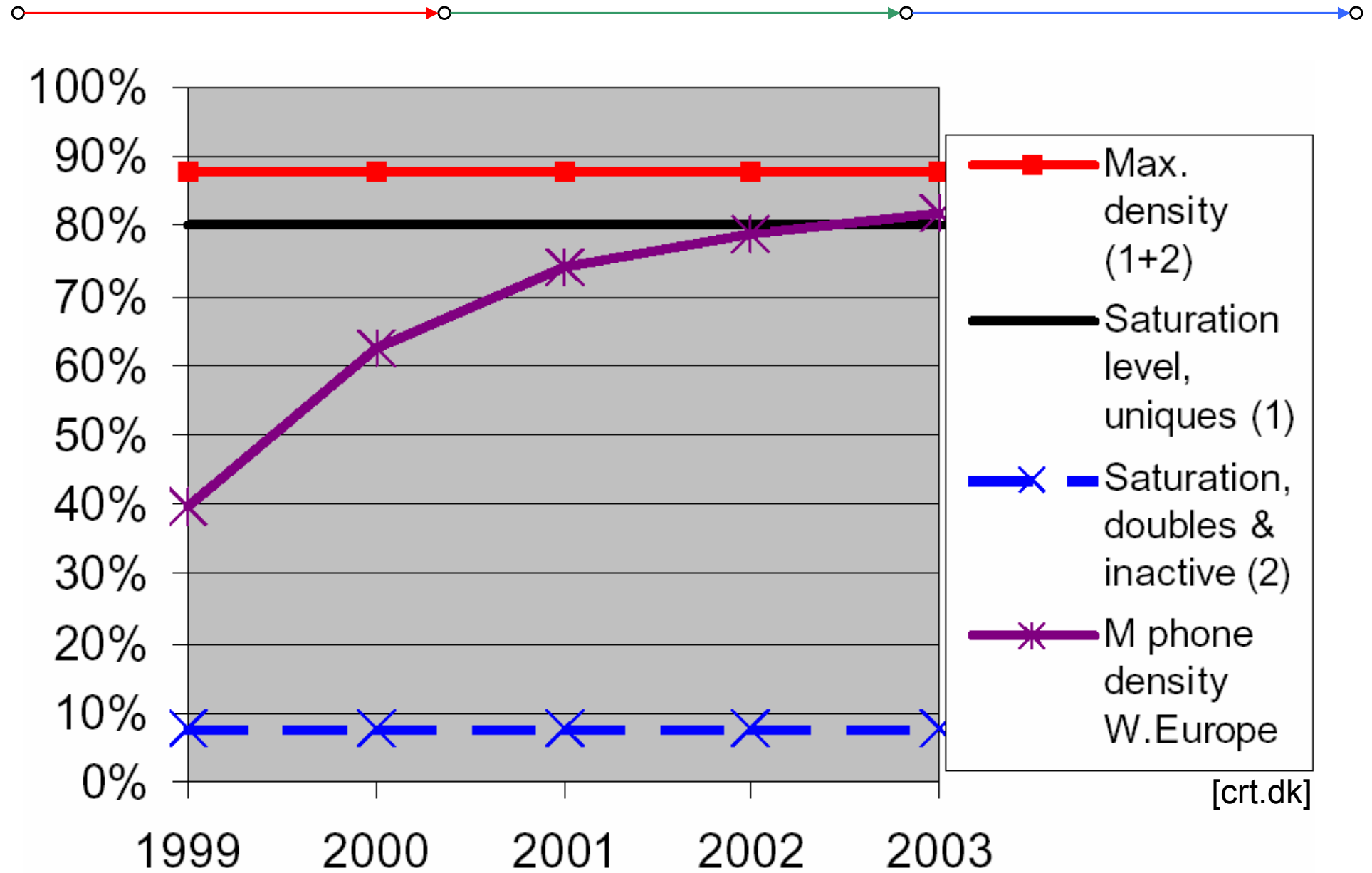
Mobile phones worldwide



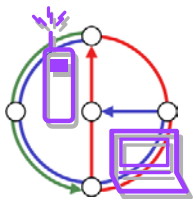
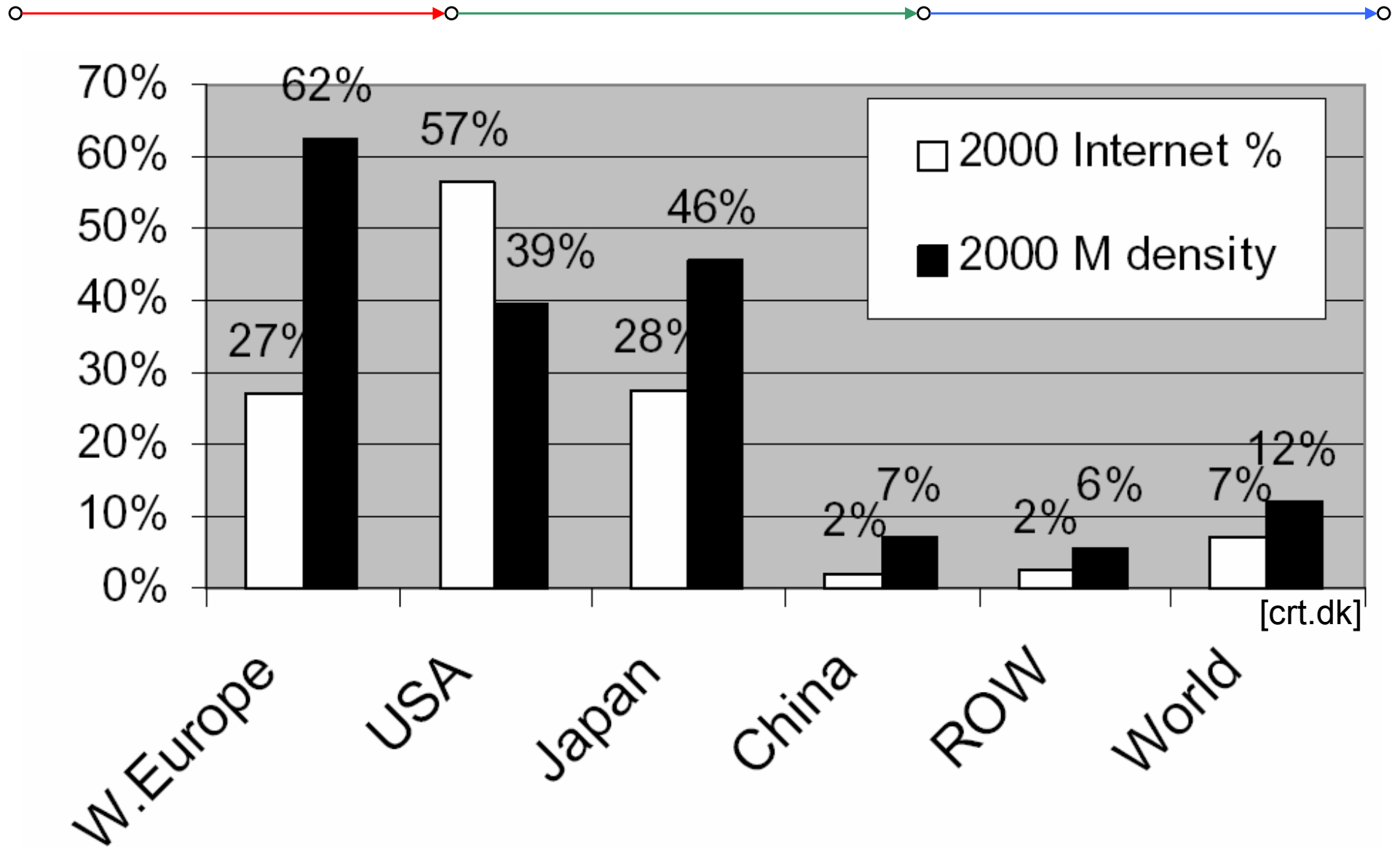
Mobile phones Top 12



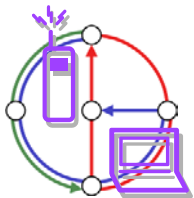
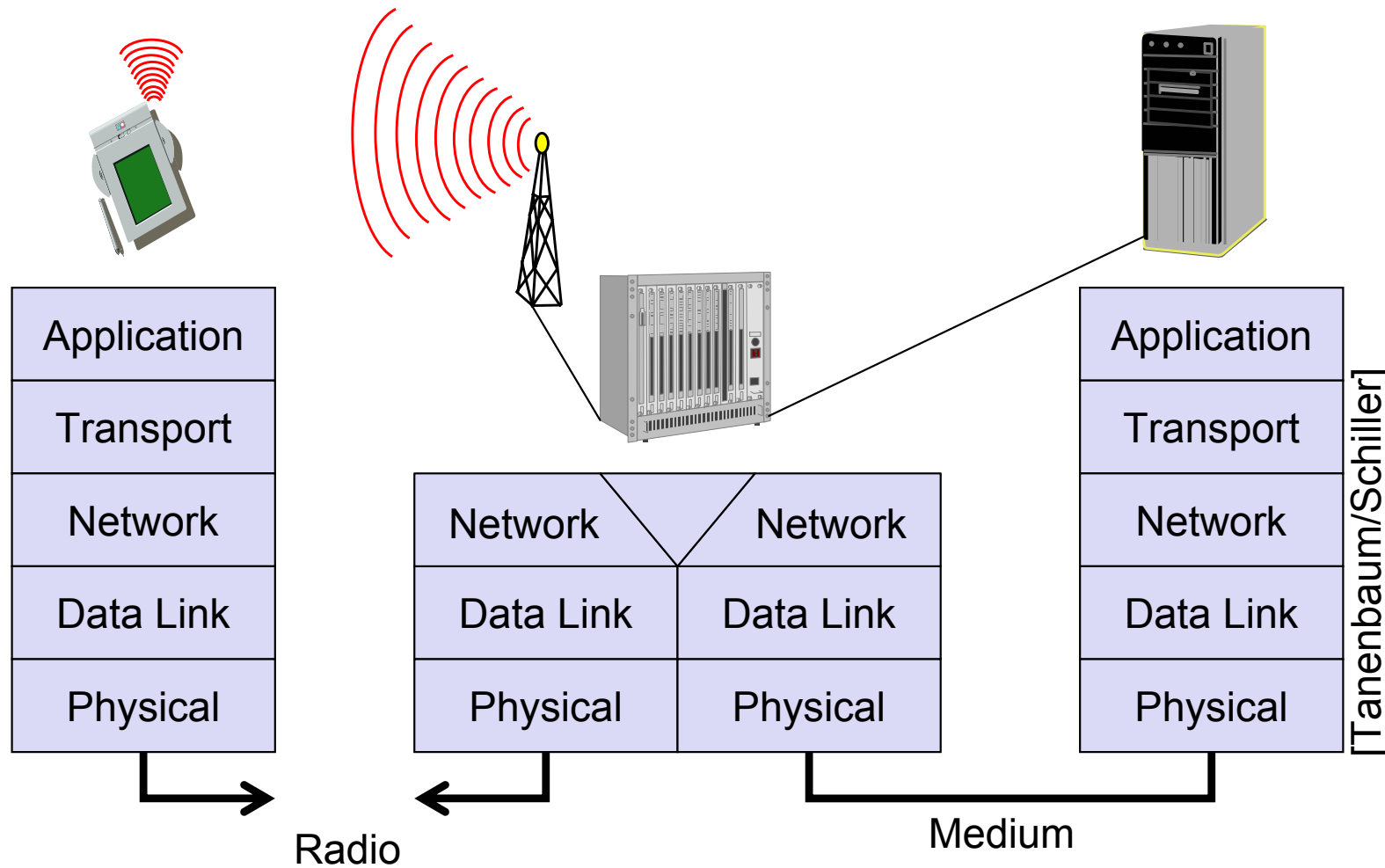
Mobile phones saturation



Internet vs. Mobile phones



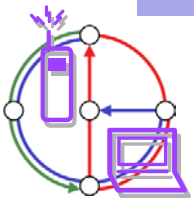
Simple reference model



Course overview: Networking Bottom – Up Approach



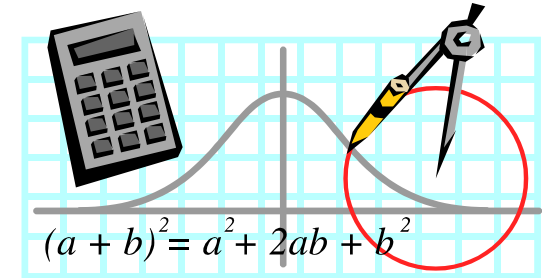
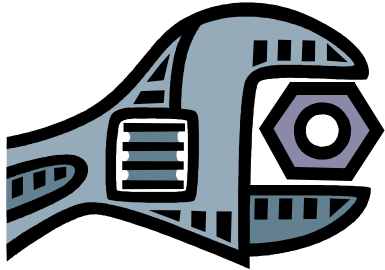
- Application layer
 - service location
 - new applications, multimedia
 - adaptive applications
- Transport layer
 - congestion and flow control
 - quality of service
- Network layer
 - addressing, routing, device location
 - hand-over
 - authentication
- Data link layer
 - media access
 - multiplexing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



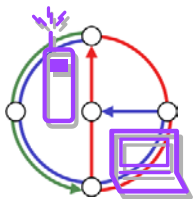
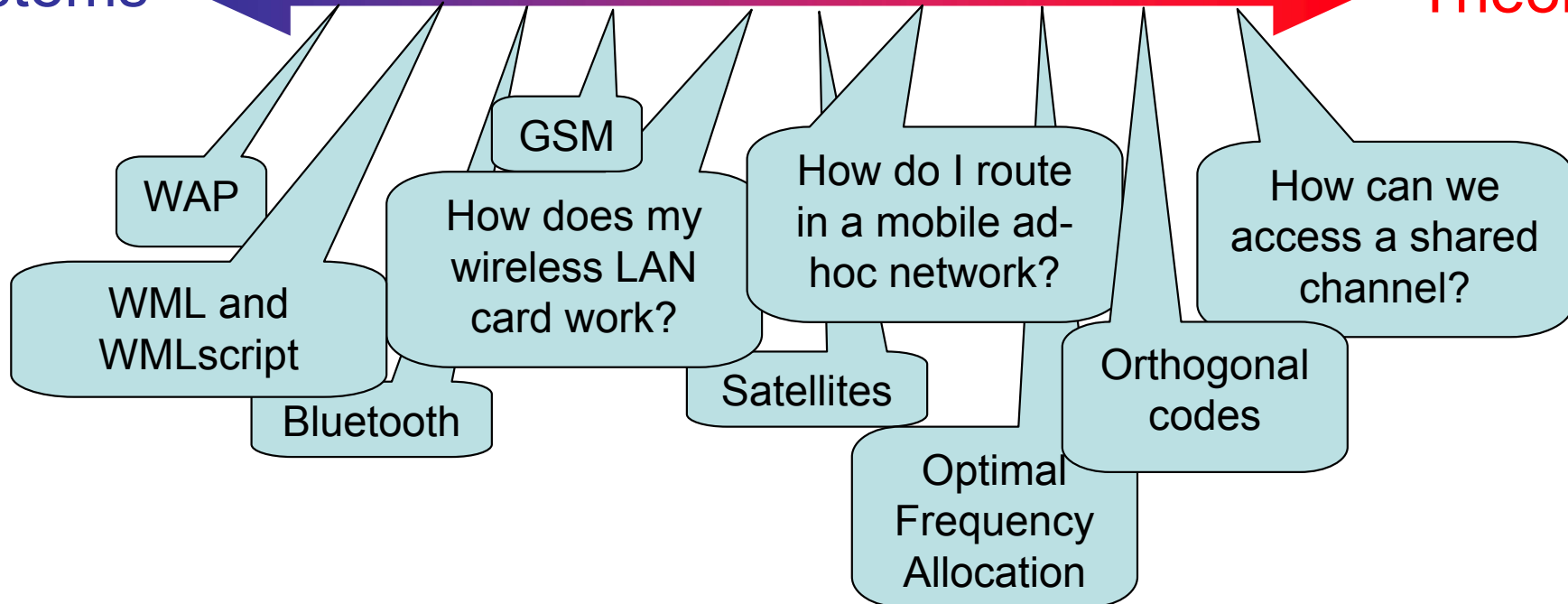


www.intuworld.com

Course overview: A large spectrum



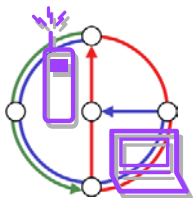
Systems  Theory



Course overview: Hands-On Exercises



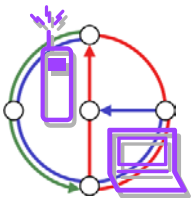
- We build a wireless LAN based ad-hoc network
 - We start with the “hello world” equivalent
 - Neighbor detection
 - Chat application
 - Multihop routing
 - Multihop chat
 - Multihop game
- Supported by
 - paper exercises
 - WAP exercises



Course overview: Lectures and *Exercises*



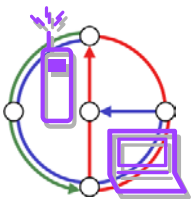
Introduction	<i>Hard- and Software Tests</i>
Physical and Link Layer	<i>"Hello World"</i>
Media Access Control	<i>Theory: Codes/MAC</i>
Local Area Networks	<i>Neighbor Detection / Chat</i>
Ad-Hoc Networks	<i>[Auffahrt]</i>
Ad-Hoc Networks 2	<i>Multihop Routing</i>
[Pfingsten]	<i>Multihop Routing 2</i>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



Course specialities



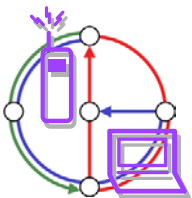
- Remember: Course for first time
 - We were clueless about the number of students
 - We were clueless about the availability of systems
 - Assistants are rookies
 - Professor is rooky
- Maximum possible spectrum of systems and theory
- New area, more open than closed questions
- Lecture and exercises are hard to synchronize
- <http://distcomp.ethz.ch/mobicomp>



Literature



- Ivan 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)

