Mobile Computing Systems

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Course Overview

- Introduction
- Data in Wireless Cellular Systems
- Data in Wireless Local Area Networks
- Internet Protocols
- TCP over Wireless Link
- Ad-Hoc Networks, Sensor Networks
- Services and Service Discovery
- System Support for Mobile Applications

Course Overview

- Introduction
  - overview of technologies for wireless communication
  - some comments on marketplace (growth, dominant technologies)
- Data in Wireless Cellular Systems
  - regulatory issues
  - AMPS/CDPD, GSM
- Data in Wireless Local Area Networks
  - Wireless LANs: IEEE 802.11
  - Personal Area Networks: Bluetooth

Course Overview

- Internet Protocols
  - Mobile IP (in IPv4 and IPv6)
  - MicroMobility Proposals
- TCP over Wireless Link
  - Datalink Layer Solutions
  - Transport Layer Solutions
  - Network Layer Solutions
- Ad Hoc Networks, Sensor Networks
  - Unicast Routing in ad-hoc networks (AODV, OLSR)
  - Multicast Routing
  - Intro to Wireless Sensor Networks

Course Overview

- Services and Service Discovery
  - RFC 2165 (Service Location Protocol)
  - Jini: Overview, Service Discovery
- System Support for Mobile Applications (if time allows)
  - File Systems and Databases
  - WWW
  - WAP (Wireless Application Protocol)
  - Java 2 ME

Course Overview

- Marking scheme:
  - Three lab assignments (20% each)
    - To be completed August 10
  - One final exam (40%)
    - In class Thursday, July 26, 1 hour

Course Overview

- References:
  - No single textbook, but relatively good/complete books are
    - Jochen Schiller, *Mobile Communications*, 2nd edition, Pearson Education Ltd. 2003, ISBN 0-321-12381-6
    - C. Siva Ram Murthy and B.S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*, Prentice Hall 2004, ISBN 0-13-147023-X (despite the title, it also covers many cellular/WLAN topics briefly).
  - Course webpage: http://kunz-pc.sce.carleton.ca/tongji/
  - List of major relevant conferences/journals/magazines provided in Appendix to course notes

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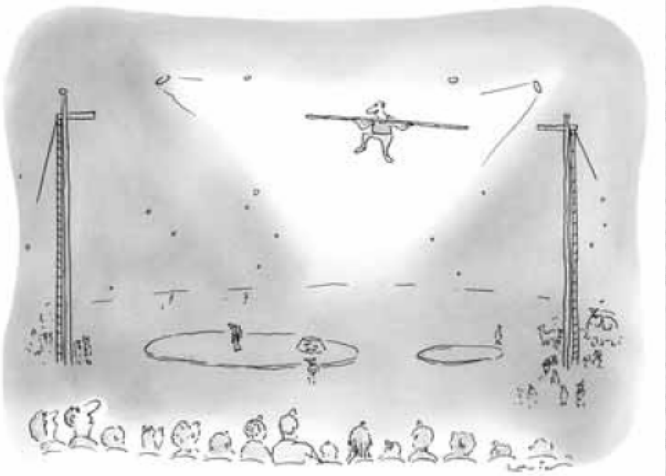
The New Yorker

"I love the convenience, but the roaming charges are killing me."

The New Yorker

"Before I read about my summer vacation, I'd like to ask that all pagers, beepers, and cell phones be turned off."

The New Yorker

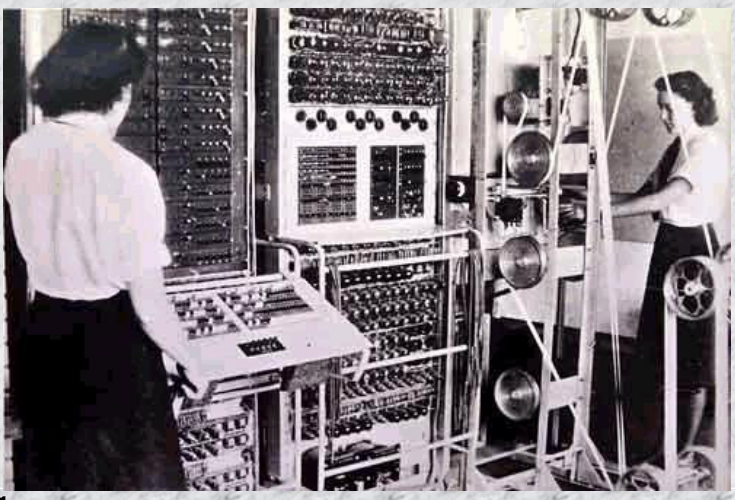


"It appears to be some kind of wireless technology."

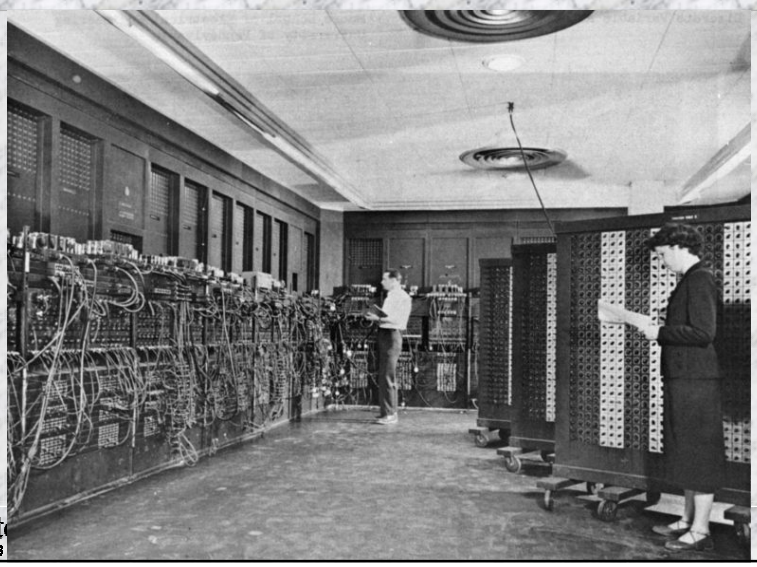
Drivers of Mobile Computing

- Portable Devices
  - Laptops
  - Cellphones
  - RIM Blackberry
- Wireless Communication
  - Cellular Systems
  - WLAN

Big Machines



Big Machines

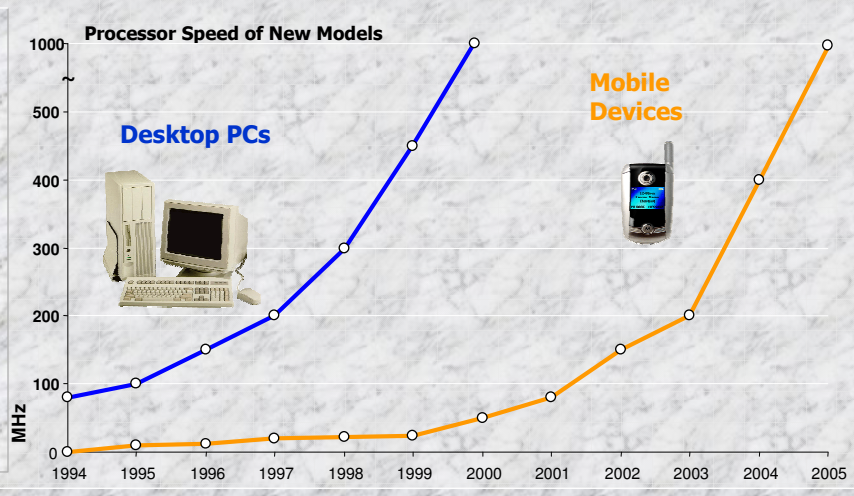


Portable Computers: The Early Days

1981: The first portable computer, the Osborne 1, is unveiled. The 25-pound unit was designed to fit underneath an airline seat. One problem for users was the machine's minuscule 5-inch display.

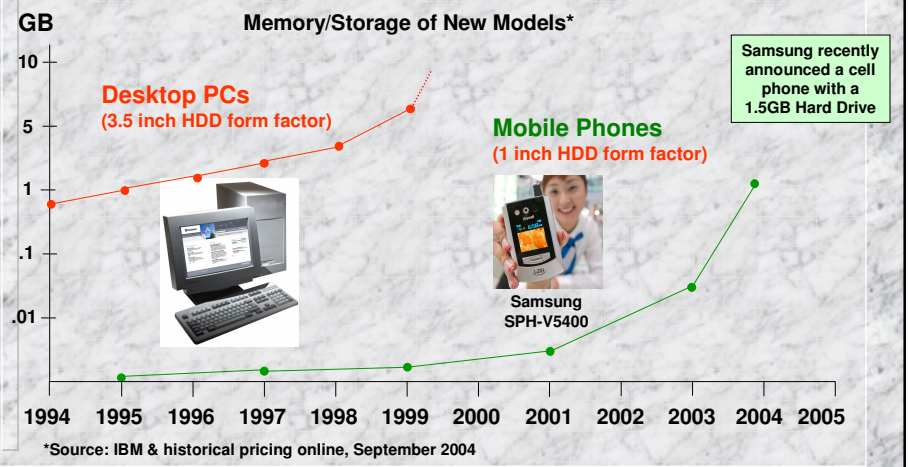
Today: Many "Sleek" Devices

Mobile Phone Processor Power Today Compares to Desktop PCs of the 90s



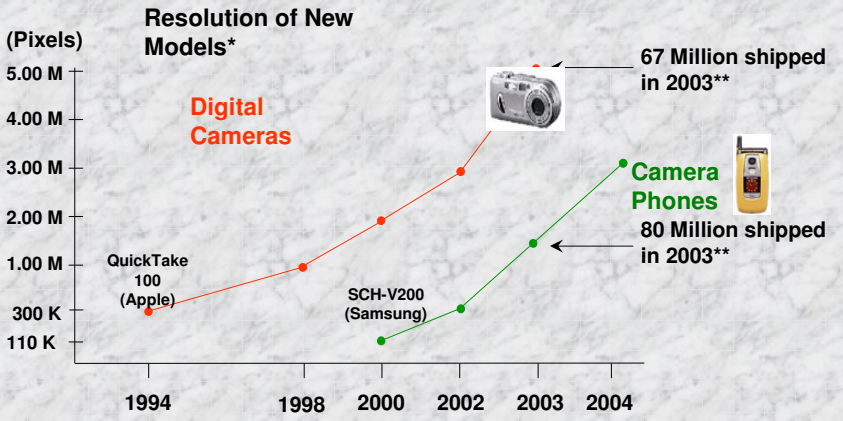
Source: Gartner Dataquest, November 2003, QUALCOMM

Mobile Phone Storage Today Compares to Desktop PCs of the 1990's



*Source: IBM & historical pricing online, September 2004

2004 Camera Phone Resolution Exceeds 2001 Digital Cameras



*Source: www.dpreview.com, www.samsung.com
**Source: Strategy Analytics, April 2004

Yesterday's Products = Today's Features?

Mobile devices

Pager
- receive only
- tiny displays
- simple text messages

PDA
- graphical displays
- character recognition
- simplified WWW

Laptop/Notebook
- fully functional
- standard applications

Sensors, embedded controllers

www.scatterweb.net

Mobile phones
- voice, data
- simple graphical displays

Palmtop
- tiny keyboard
- simple versions of standard applications

performance

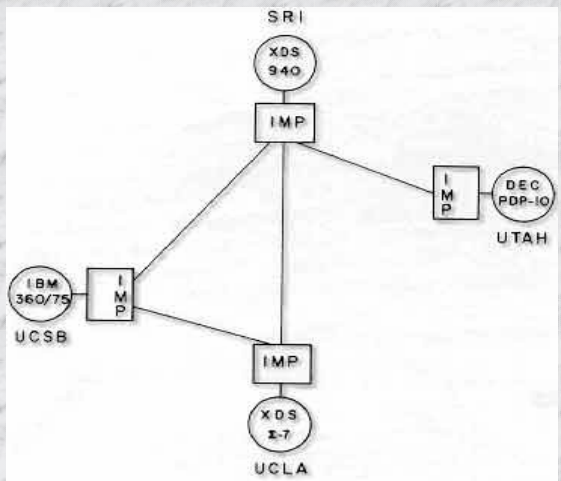
Computers for the next decades?

- Computers are integrated
  - small, cheap, portable, replaceable - no more separate devices
- Technology is in the background
  - computer are aware of their environment and adapt (“location awareness”)
  - computer recognize the location of the user and react appropriately (e.g., call forwarding, fax forwarding, “context awareness”)
- 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 cubic meter
  - multiple wireless interfaces: wireless LANs, wireless WANs, regional wireless telecommunication networks etc. („overlay networks“)

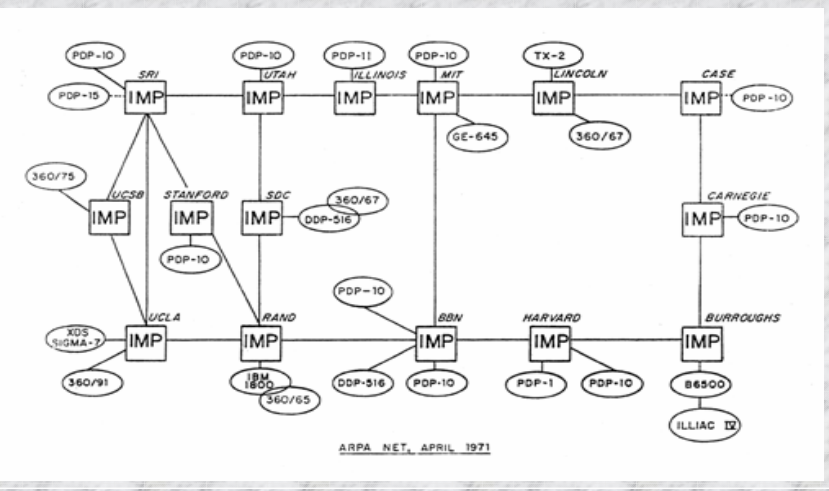
Effects of device portability

- Power consumption
  - limited computing power, low quality displays, small disks due to limited battery capacity
  - CPU: power consumption ~ CV2f
    - C: internal capacity, reduced by integration
    - V: supply voltage, can be reduced to a certain limit
    - f: clock frequency, can be reduced temporally
- Loss of data
  - higher probability, has to be included in advance into the design (e.g., defects, theft)
- Limited user interfaces
  - compromise between size of fingers and portability
  - integration of character/voice recognition, abstract symbols
- Limited memory
  - limited value of mass memories with moving parts
  - flash-memory or ? as alternative

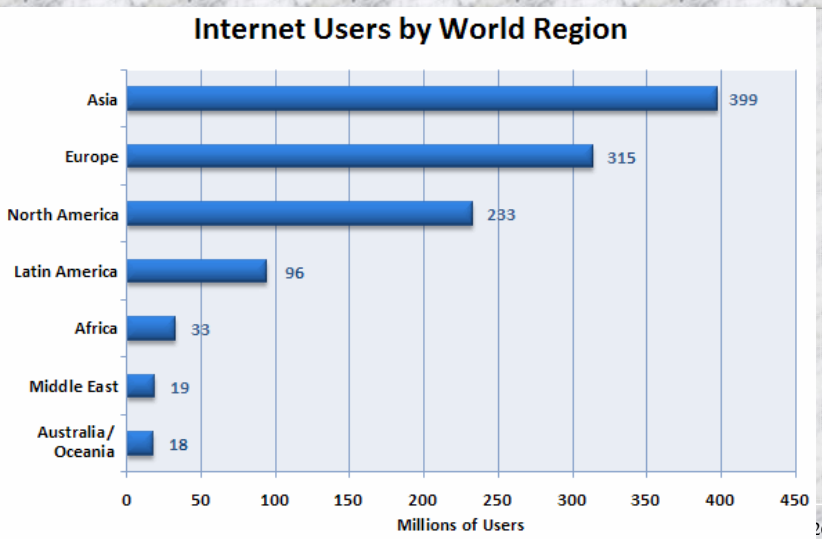
Internet: From Humble Beginnings in 1969 ....



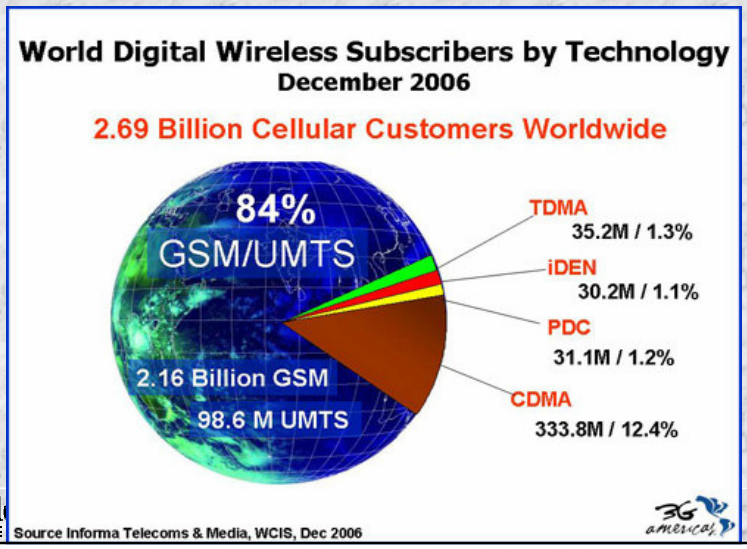
Internet: … slowly….



Internet: … to a global communications network in 2007

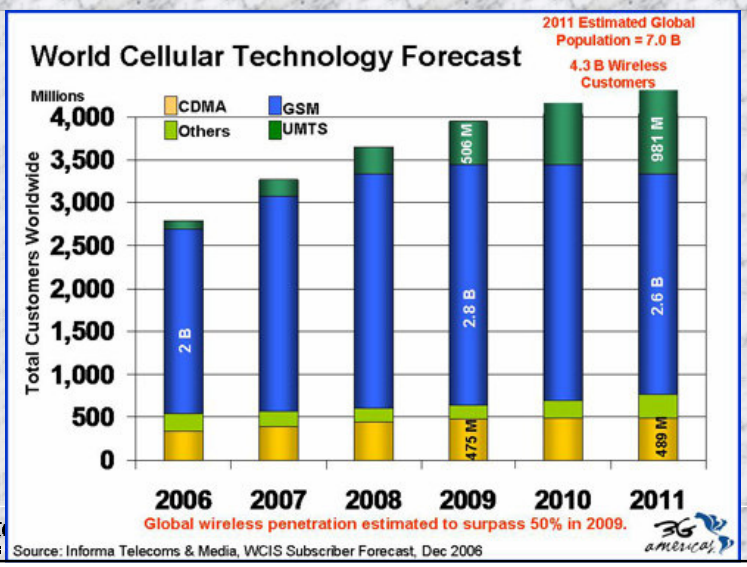


Wireless Communication: Cellular Networks Today



Source Informa Telecoms & Media, WCIS, Dec 2006

Wireless Communication: Cellular Networks Tomorrow



Source: Informa Telecoms & Media, WCIS Subscriber Forecast, Dec 2006

Evolution of Cellular Networks

- 1G (AMPS, etc)
  - Analog, primarily voice, less secure, low bit data rate
- 2G (GSM, CDMA, etc) and 2.5 G (GPRS)
  - Digital, more secure, voice and data
- 3G (W-CDMA, CDMA2000, etc) and 3.5 G
  - Digital, multimedia, global roaming across a single network, 144Kbps to several Mbps, limited IP interoperability
- 4G (TBD)
  - Global roaming across multiple wireless networks, 10-100 Mbps, IP interoperability for seamless mobile Internet

Source: Evolution and Emerging Issues in Mobile Wireless Networks, Communications of the ACM, June 2007, pages 38-43

Mobile communication

- Two aspects of mobility:
  - user mobility: users communicate (wireless) “anytime, anywhere, with anyone”
  - device portability: devices can be connected anytime, anywhere to the network
- Wireless vs. mobile / Examples

×	×	stationary computer
×	✓	notebook in a hotel
✓	×	wireless LANs in historic buildings
✓	✓	Personal Digital Assistant (PDA)

- The demand for mobile communication creates the need for integration of wireless networks into existing fixed networks:
  - local area networks: standardization of IEEE 802.11, ETSI (HIPERLAN)
  - Internet: Mobile IP extension of the internet protocol IP
  - wide area networks: e.g., internetworking of GSM and ISDN

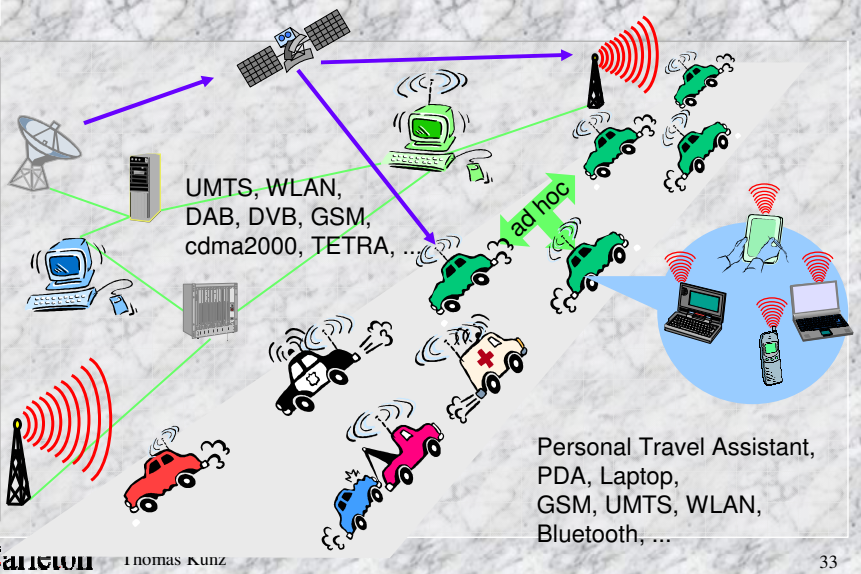
Wireless networks in comparison to fixed networks

- 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., 53kbit/s with GSM/GPRS
- Higher delays, higher jitter
  - connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems
- 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

Applications I

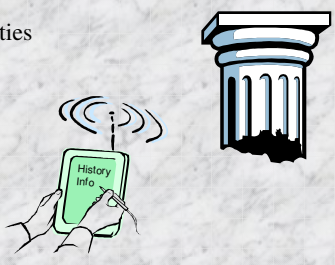
- Vehicles
  - transmission of news, road condition, weather, music via DAB
  - personal communication using GSM
  - position via GPS
  - local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
  - vehicle data (e.g., from busses, high-speed trains) can be transmitted in advance for maintenance
- Emergencies
  - early transmission of patient data to the hospital, current status, first diagnosis
  - replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire etc.
  - crisis, war, ...

Typical application: road traffic



Applications II

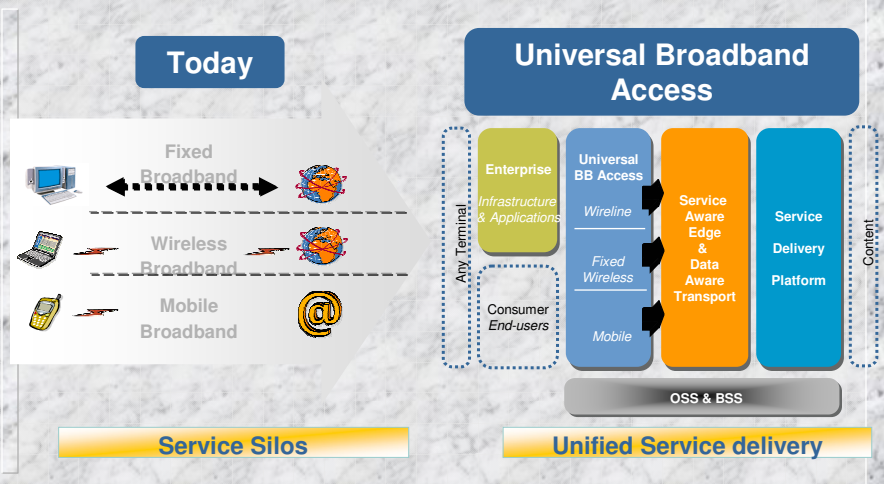
- Traveling salesmen
  - direct access to customer files stored in a central location
  - consistent databases for all agents
  - mobile office
- Replacement of fixed networks
  - remote sensors, e.g., weather, earth activities
  - flexibility for trade shows
  - LANs in historic buildings
- Entertainment, education, ...
  - outdoor Internet access
  - intelligent travel guide with up-to-date location dependent information
  - ad-hoc networks for multi user games



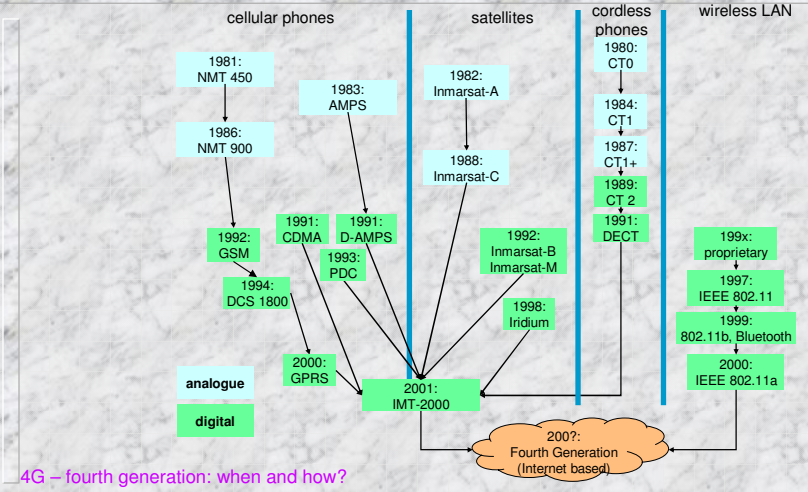
Location dependent services

- Location aware services
  - what services, e.g., printer, fax, phone, server etc. exist in the local environment
- Follow-on services
  - automatic call-forwarding, transmission of the actual workspace to the current location
- Information services
  - „push“: e.g., current special offers in the supermarket
  - „pull“: e.g., where is the Black Forrest Cherry Cake?
- Support services
  - caches, intermediate results, state information etc. „follow“ the mobile device through the fixed network
- Privacy
  - who should gain knowledge about the location

The Holy Grail: Universal Broadband Access

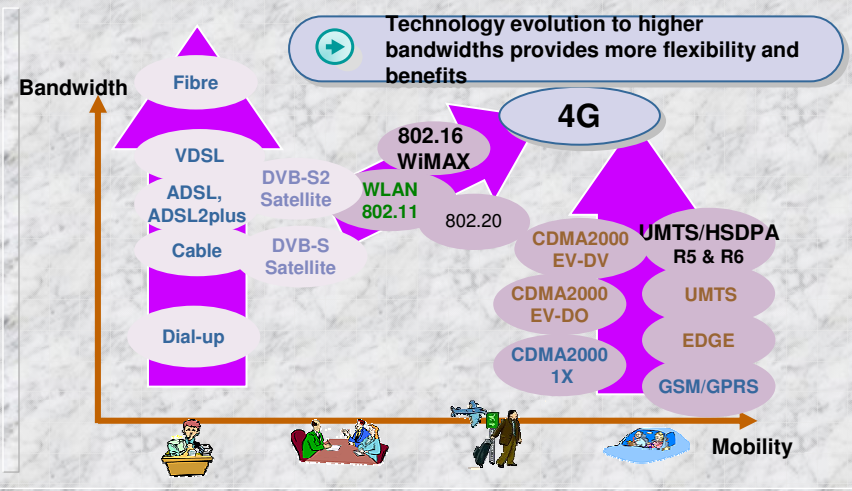


Wireless systems: overview of the development

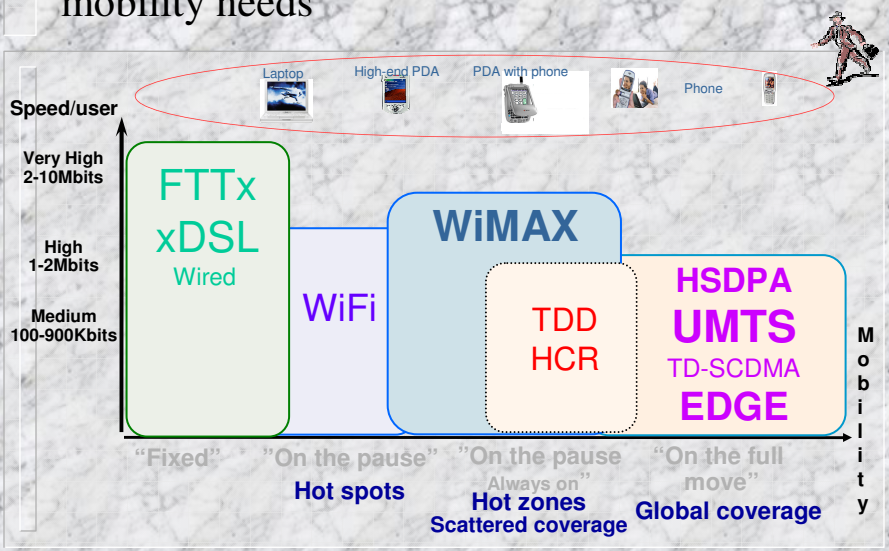


4G – fourth generation: when and how?

Universal Broadband Access: Higher Bandwidth



Complementary access solutions for different mobility needs



TCP/IP and Mobile Computing

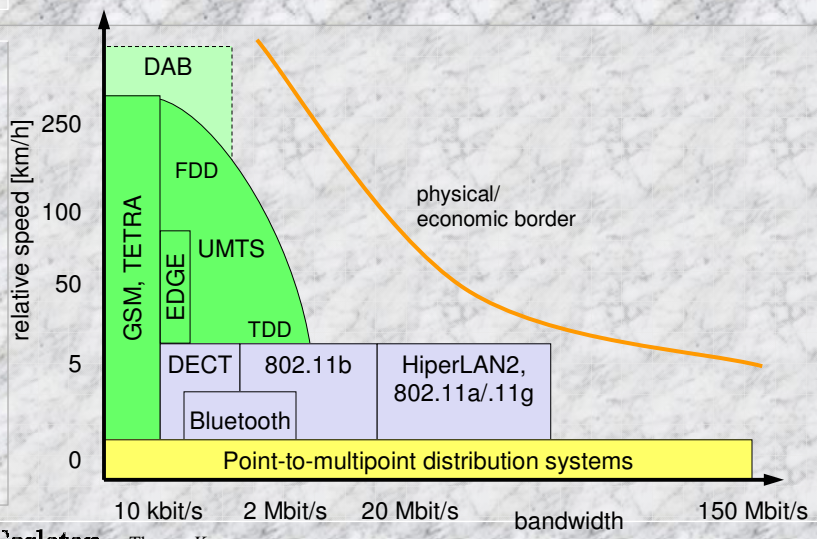
- TCP/IP core designed 30+ years ago
- Extremely successful:
  - Size of Internet
  - Integration of different networking technologies
- So integrating all these new wireless networks using TCP/IP obviously the way to go, right? ☺

Well…..

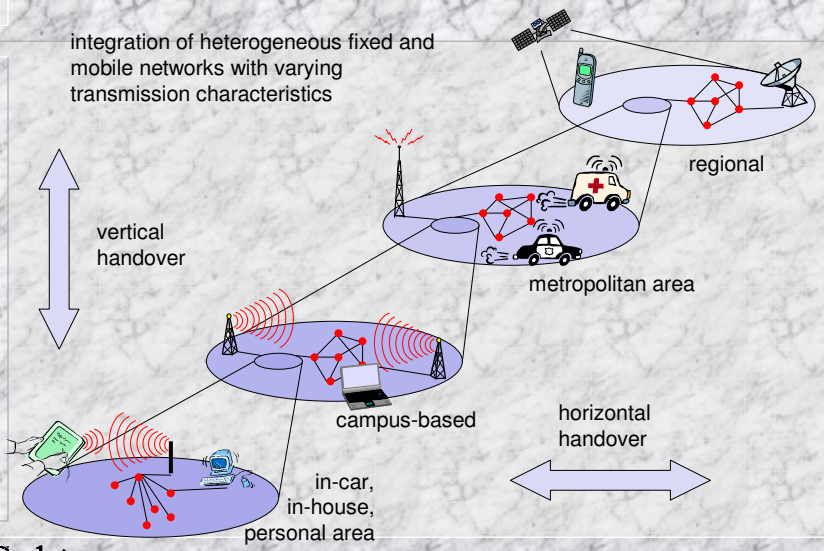
- TCP/IP protocols are not quite without problems of their own (even for wired networks)
  - Lack of QoS
  - Weak Security
  - "Business model" with intelligence at the edge does not suit operators all that well

→ most cellular network access netwoks and cores are NOT based on TCP/IP (though this is changing)

Wireless access technologies: No uniform standard (similar to Ethernet) in sight



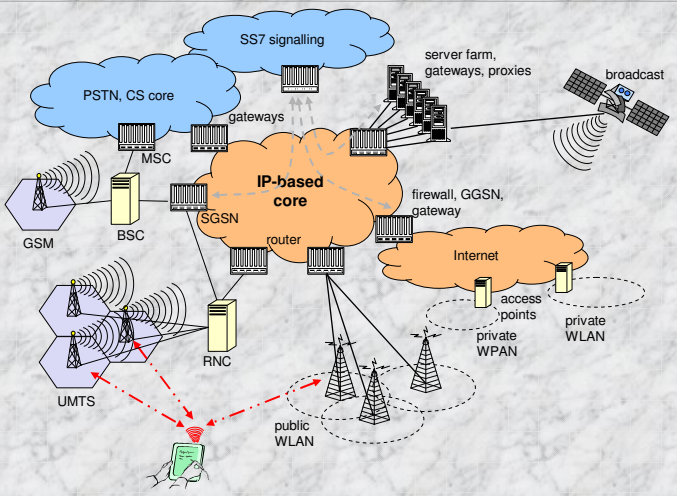
Overlay Networks - the global goal



Key features of future mobile and wireless networks

- Improved radio technology and antennas
  - smart antennas, beam forming, multiple-input multiple-output (MIMO)
    - space division multiplex to increase capacity, benefit from multipath
  - software defined radios (SDR)
    - use of different air interfaces, download new modulation/coding/...
    - requires a lot of processing power (UMTS RF 10000 GIPS)
  - dynamic spectrum allocation
    - spectrum on demand results in higher overall capacity
- Core network convergence
  - IP-based, quality of service, mobile IP
- Ad-hoc technologies
  - spontaneous communication, power saving, redundancy
- Simple and open service platform
  - intelligence at the edge, not in the network (as with IN)
  - more service providers, not network operators only

Example IP-based 4G/Next G/… network



Potential problems

- Quality of service
  - Today's Internet is best-effort
  - Integrated services did not work out
  - Differentiated service have to prove scalability and manageability
  - What about the simplicity of the Internet? DoS attacks on QoS?
- Internet protocols are well known…
  - …also to attackers, hackers, intruders
    - security by obscurity does not really work, however, closed systems provide some protection
- Reliability, maintenance
  - Open question if Internet technology is really cheaper as soon as high reliability (99.9999%) is required plus all features are integrated
- Missing charging models
  - Charging by technical parameters (volume, time) is not reasonable
  - Pay-per-application may make much more sense
- **Killer application? There is no single killer application!**
  - Choice of services and seamless access to networks determine the success

Challenges

- Wireless Technology
  - Higher bandwidth
  - Cheaper radios (Bluetooth, ZigBee)
  - Operate in licence-free spectrum, or co-exist with other services/exploit unused portions of frequency band
- Services
  - Networks are more than dump bitpipes (3G was initially big on services, difference between "beyond 3G" and 4G)
- Internet Protocols
  - Existing protocols ill-suited to wireless transmissions and mobile end-hosts
  - New protocol requirements (mobility mgmt, different types of handoff, QoS, security)
  - Yet another "nail in the coffin" for IPv4 (3 billion handsets!)

Mobile Computing is Fun