Mobile Communications

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FU Berlin
Computer Science
Computer Systems & Telematics

Prof. Dr.-Ing. Jochen Schiller

http://www.jochenschiller.de/
schiller@computer.org

Overview of the lecture

- Introduction
  - Use-cases, applications
  - Definition of terms
  - Challenges, history
- Wireless Transmission
  - frequencies & regulations
  - signals, antennas, signal propagation
  - multiplexing, modulation, spread spectrum, cellular system
- Media Access
  - motivation, SDMA, FDMA, TDMA (fixed, Aloha, CSMA, DAMA, PRMA, MACA, collision avoidance, polling), CDMA
- Wireless Telecommunication Systems
  - GSM, HSCSD, GPRS, DECT, TETRA, UMTS, IMT-2000
- Satellite Systems
  - GEO, LEO, MEO, routing, handover
- Broadcast Systems
  - DAB, DVB
- Wireless LANs
  - Basic Technology
  - IEEE 802.11a/b/g, .15, Bluetooth
- Network Protocols
  - Mobile IP
  - Ad-hoc networking
  - Routing
- Transport Protocols
  - Reliable transmission
  - Flow control
  - Quality of Service
- Support for Mobility
  - File systems, WWW, WAP, i-mode, J2ME, ...
- Outlook

Chapter 1:

Introduction

- A case for mobility – many aspects
- History of mobile communication
- Market
- Areas of research

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“)

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	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

Applications I

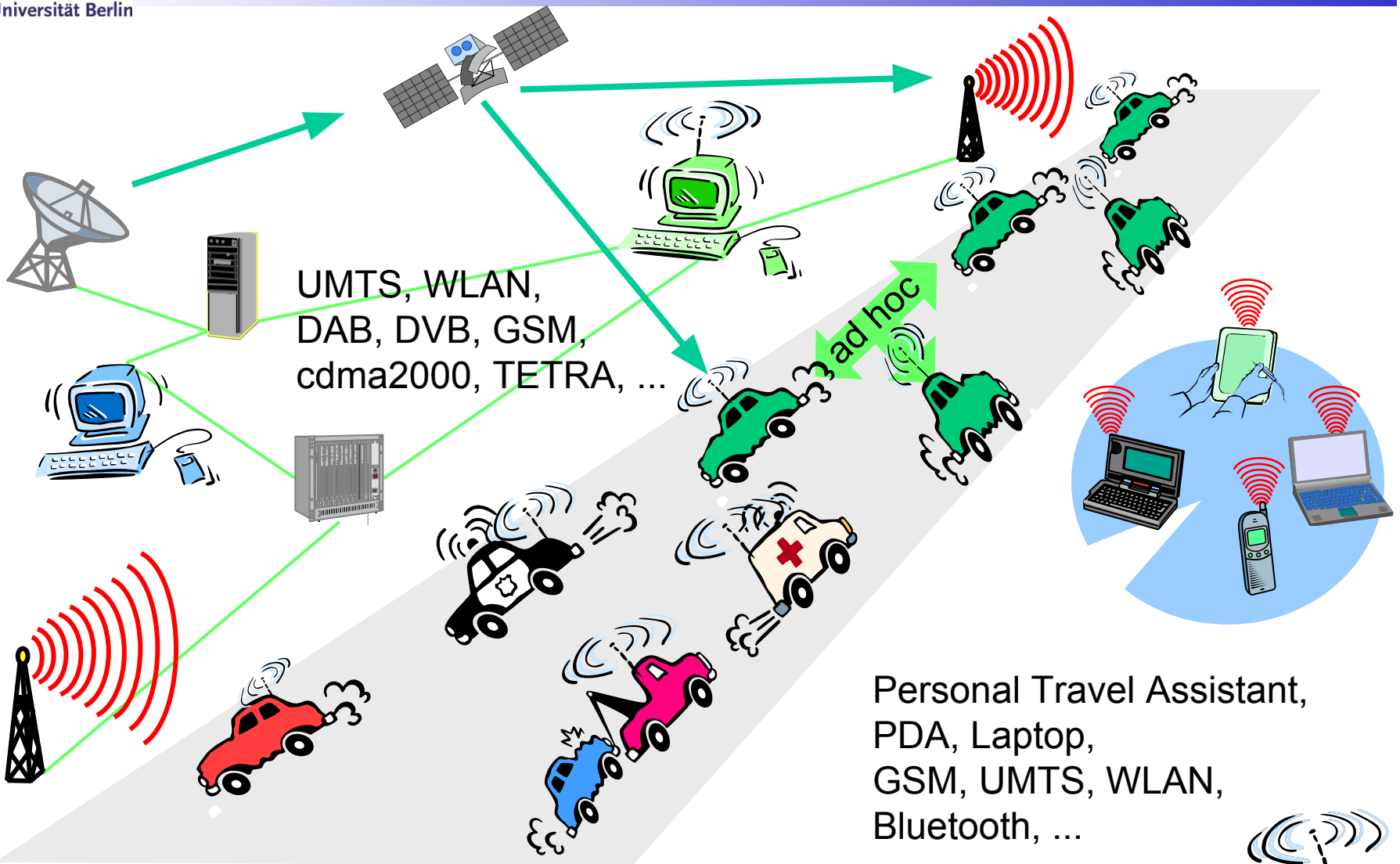
Vehicles

- 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

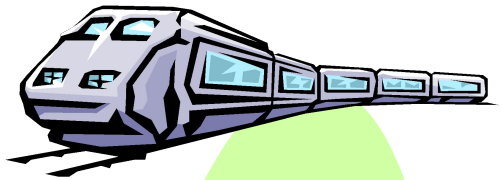


Mobile and wireless services – Always Best Connected

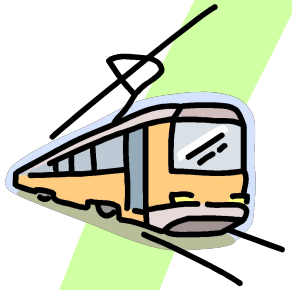
DSL/ WLAN
3 Mbit/s

GSM/GPRS 53 kbit/s
Bluetooth 500 kbit/s

UMTS, GSM
115 kbit/s



LAN
100 Mbit/s,
WLAN
54 Mbit/s



UMTS
2 Mbit/s

GSM/EDGE 384 kbit/s,
DSL/WLAN 3 Mbit/s

GSM 115 kbit/s,
WLAN 11 Mbit/s

UMTS, GSM
384 kbit/s

Applications II

Travelling 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

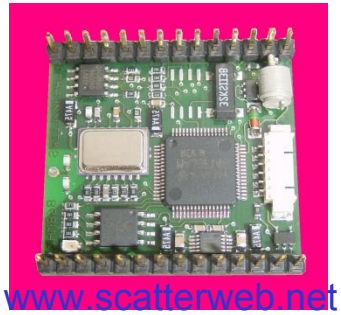
Mobile devices

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.scattenweb.net

Mobile phones
- voice, data
- simple graphical displays

Palmtop
- tiny keyboard
- simple versions of standard applications

performance

Effects of device portability

Power consumption

- limited computing power, low quality displays, small disks due to limited battery capacity
- CPU: power consumption ~ CV^2f
  - 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

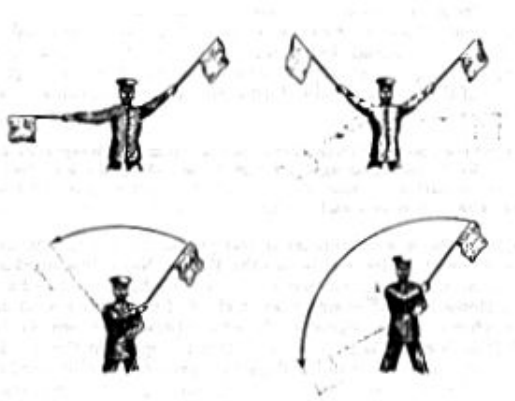
Wireless networks in comparison to fixed networks

- 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

Early history of wireless communication

Many people in history used light for communication

- heliographs, flags („semaphore“), ...
- 150 BC smoke signals for communication; (Polybius, Greece)
- 1794, optical telegraph, Claude Chappe



Here electromagnetic waves are of special importance:

- 1831 Faraday demonstrates electromagnetic induction
- J. Maxwell (1831-79): theory of electromagnetic Fields, wave equations (1864)
- H. Hertz (1857-94): demonstrates with an experiment the wave character of electrical transmission through space (1888, in Karlsruhe, Germany, at the location of today’s University of Karlsruhe)

History of wireless communication I

1896 Guglielmo Marconi

- first demonstration of wireless telegraphy (digital!)
- long wave transmission, high transmission power necessary (> 200kw)

1907 Commercial transatlantic connections

- huge base stations (30 100m high antennas)

1915 Wireless voice transmission New York - San Francisco

1920 Discovery of short waves by Marconi

- reflection at the ionosphere
- smaller sender and receiver, possible due to the invention of the vacuum tube (1906, Lee DeForest and Robert von Lieben)

1926 Train-phone on the line Hamburg - Berlin

- wires parallel to the railroad track

History of wireless communication II

1928 many TV broadcast trials (across Atlantic, color TV, TV news)

1933 Frequency modulation (E. H. Armstrong)

1958 A-Netz in Germany

- analog, 160MHz, connection setup only from the mobile station, no handover, 80% coverage, 1971 11000 customers

1972 B-Netz in Germany

- 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

1979 NMT at 450MHz (Scandinavian countries)

1982 Start of GSM-specification

- goal: pan-European digital mobile phone system with roaming

1983 Start of the American AMPS (Advanced Mobile Phone System, analog)

1984 CT-1 standard (Europe) for cordless telephones

History of wireless communication III

1986 C-Netz in Germany

- analog voice transmission, 450MHz, hand-over possible, digital signaling, automatic location of mobile device
- Was in use until 2000, services: FAX, modem, X.25, e-mail, 98% coverage

1991 Specification of DECT

- Digital European Cordless Telephone (today: Digital Enhanced Cordless Telecommunications)
- 1880-1900MHz, ~100-500m range, 120 duplex channels, 1.2Mbit/s data transmission, voice encryption, authentication, up to several 10000 user/km^2, used in more than 50 countries

1992 Start of GSM

- in D as D1 and D2, fully digital, 900MHz, 124 channels
- automatic location, hand-over, cellular
- roaming in Europe - now worldwide in more than 200 countries
- services: data with 9.6kbit/s, FAX, voice, ...

History of wireless communication IV

1994 E-Netz in Germany
- GSM with 1800MHz, smaller cells
- As Eplus in D (1997 98% coverage of the *population*)

1996 HiperLAN (High Performance Radio Local Area Network)
- ETSI, standardization of type 1: 5.15 - 5.30GHz, 23.5Mbit/s
- recommendations for type 2 and 3 (both 5GHz) and 4 (17GHz) as wireless ATM-networks (up to 155Mbit/s)

1997 Wireless LAN - IEEE802.11
- IEEE standard, 2.4 - 2.5GHz and infrared, 2Mbit/s
- already many (proprietary) products available in the beginning

1998 Specification of GSM successors
- for UMTS (Universal Mobile Telecommunication System) as European proposals for IMT-2000

Iridium
- 66 satellites (+6 spare), 1.6GHz to the mobile phone

History of wireless communication V

1999 Standardization of additional wireless LANs
- IEEE standard 802.11b, 2.4-2.5GHz, 11Mbit/s
- Bluetooth for piconets, 2.4Ghz, <1Mbit/s

Decision about IMT-2000
- Several “members” of a “family”: UMTS, cdma2000, DECT, …

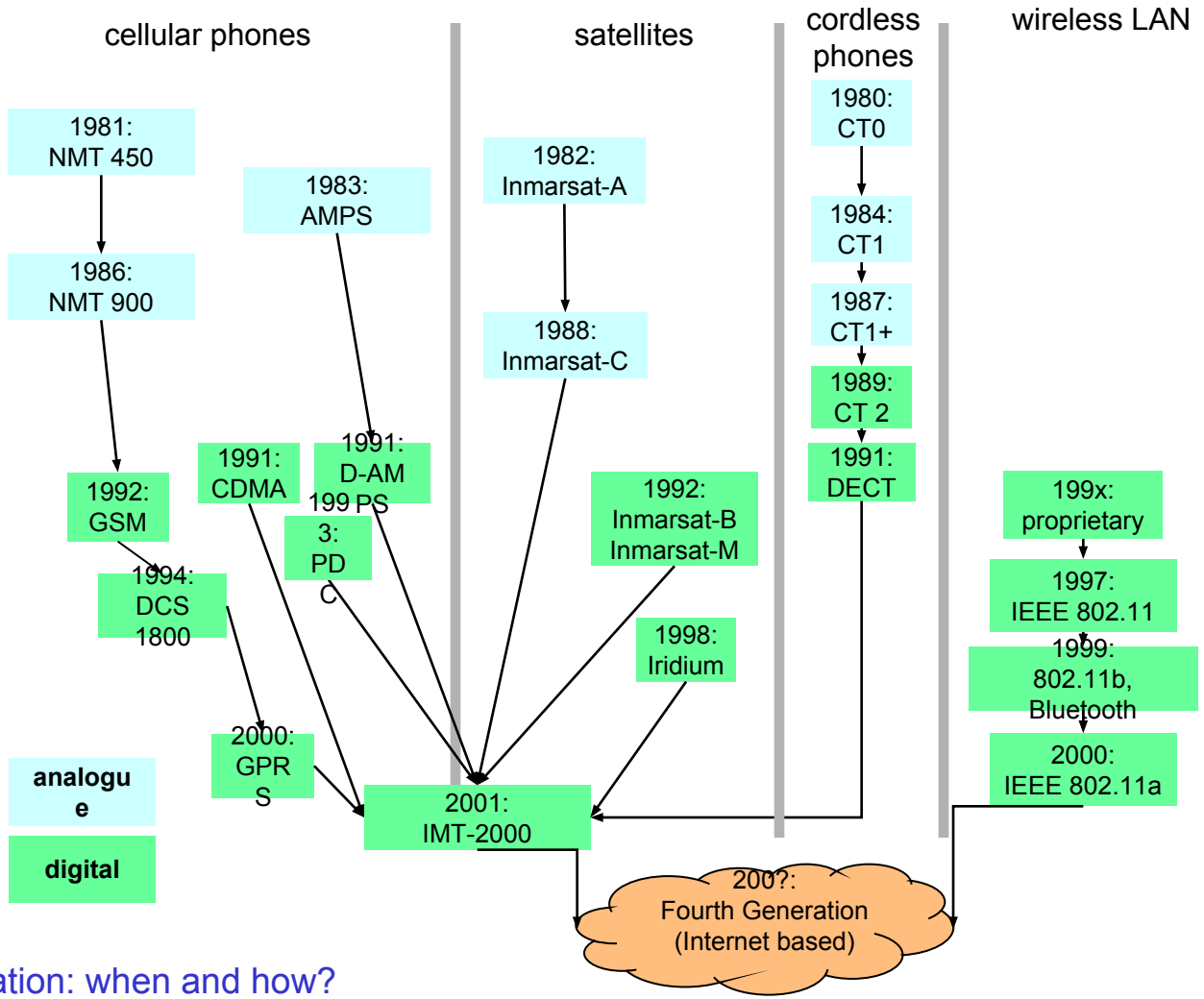
Start of WAP (Wireless Application Protocol) and i-mode
- First step towards a unified Internet/mobile communicaiton system
- Access to many services via the mobile phone

2000 GSM with higher data rates
- HSCSD offers up to 57,6kbit/s
- First GPRS trials with up to 50 kbit/s (packet oriented!)

UMTS auctions/beauty contests
- Hype followed by disillusionment (50 B$ payed in Germany for 6 licenses!)

2001 Start of 3G systems
- Cdma2000 in Korea, UMTS tests in Europe, Foma (almost UMTS) in Japan

Wireless systems: overview of the development



4G – fourth generation: when and how?

Foundation: 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

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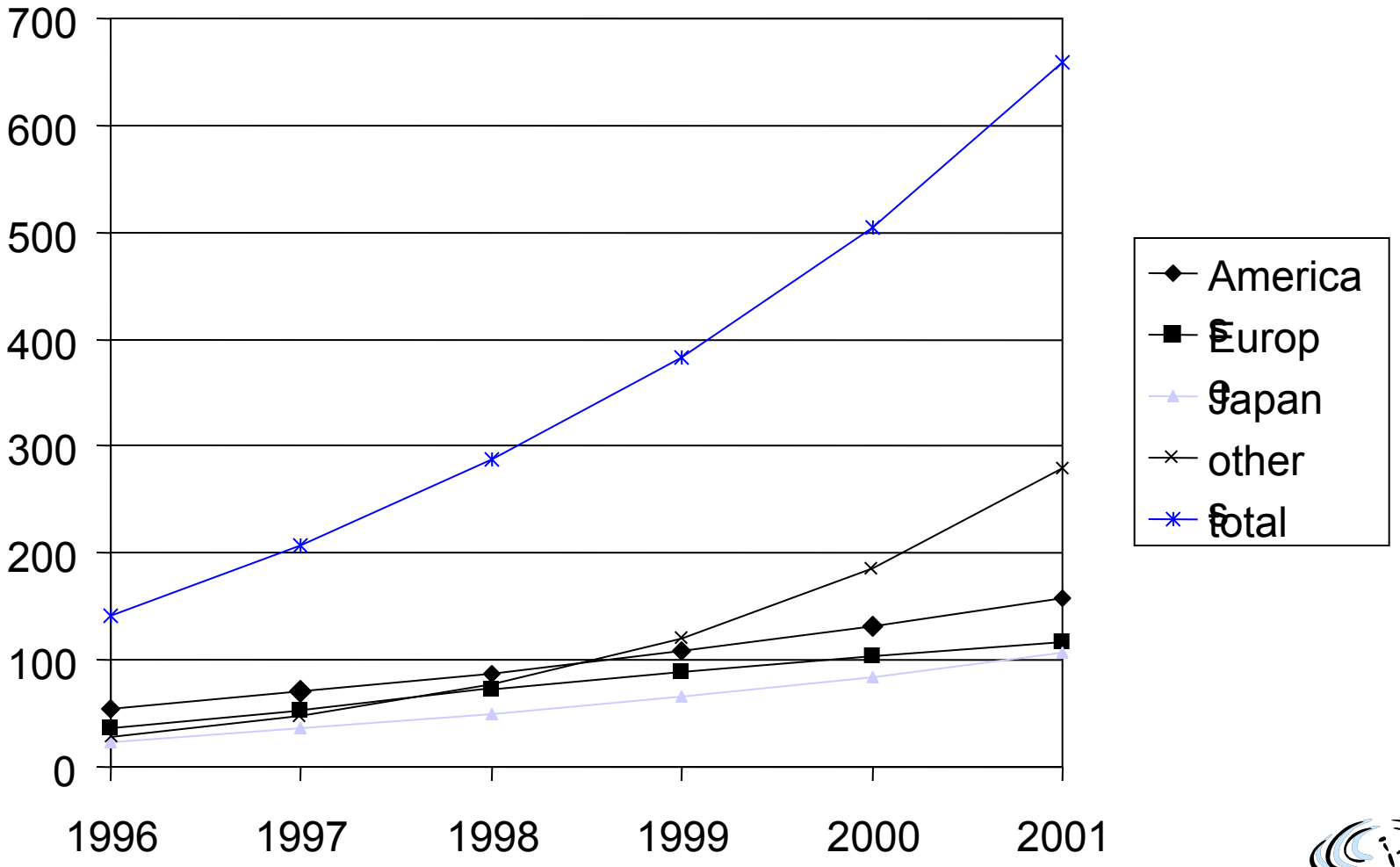
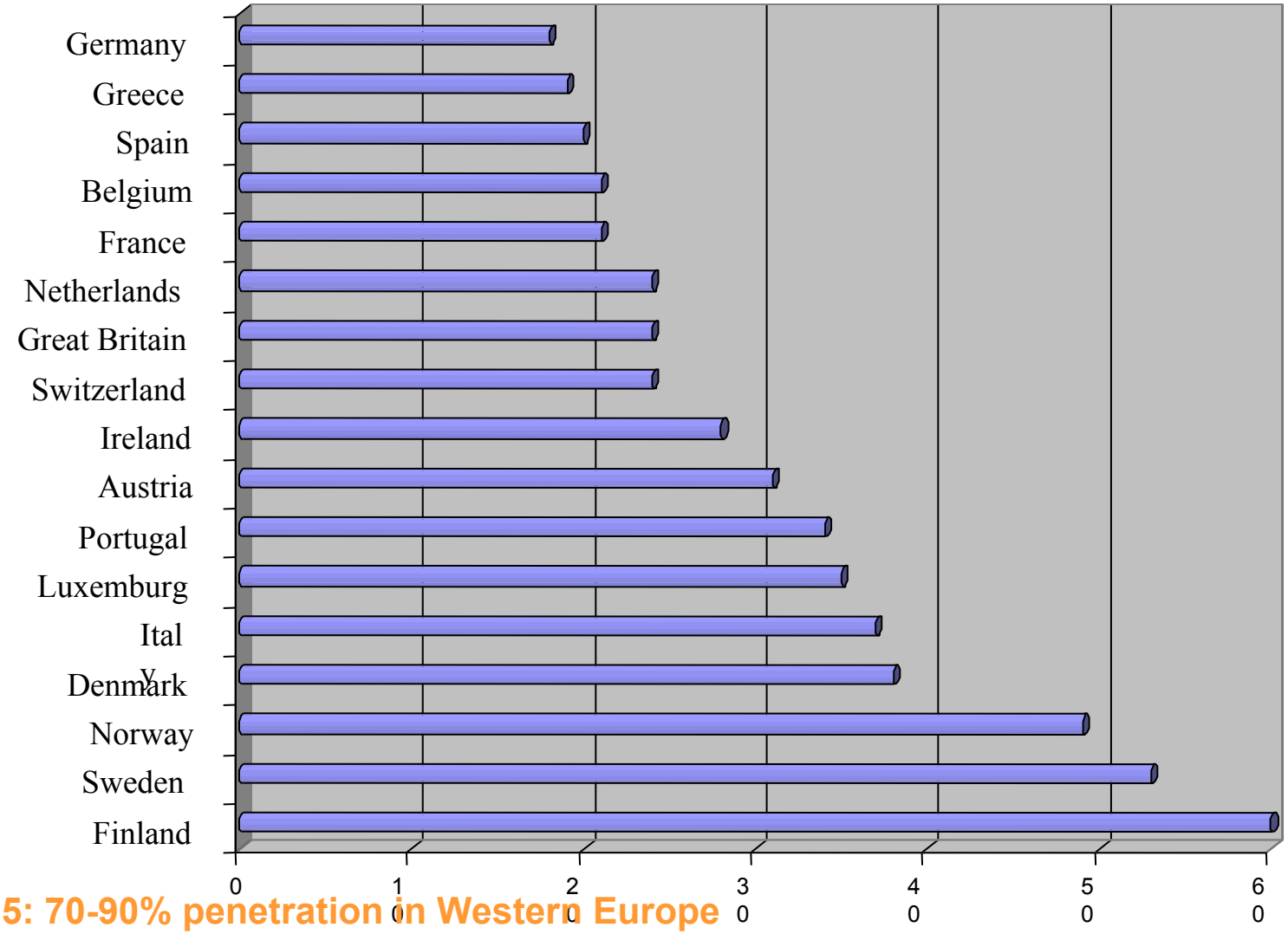
http://www.itu.int/imt

Worldwide wireless subscribers (old prediction 1998)

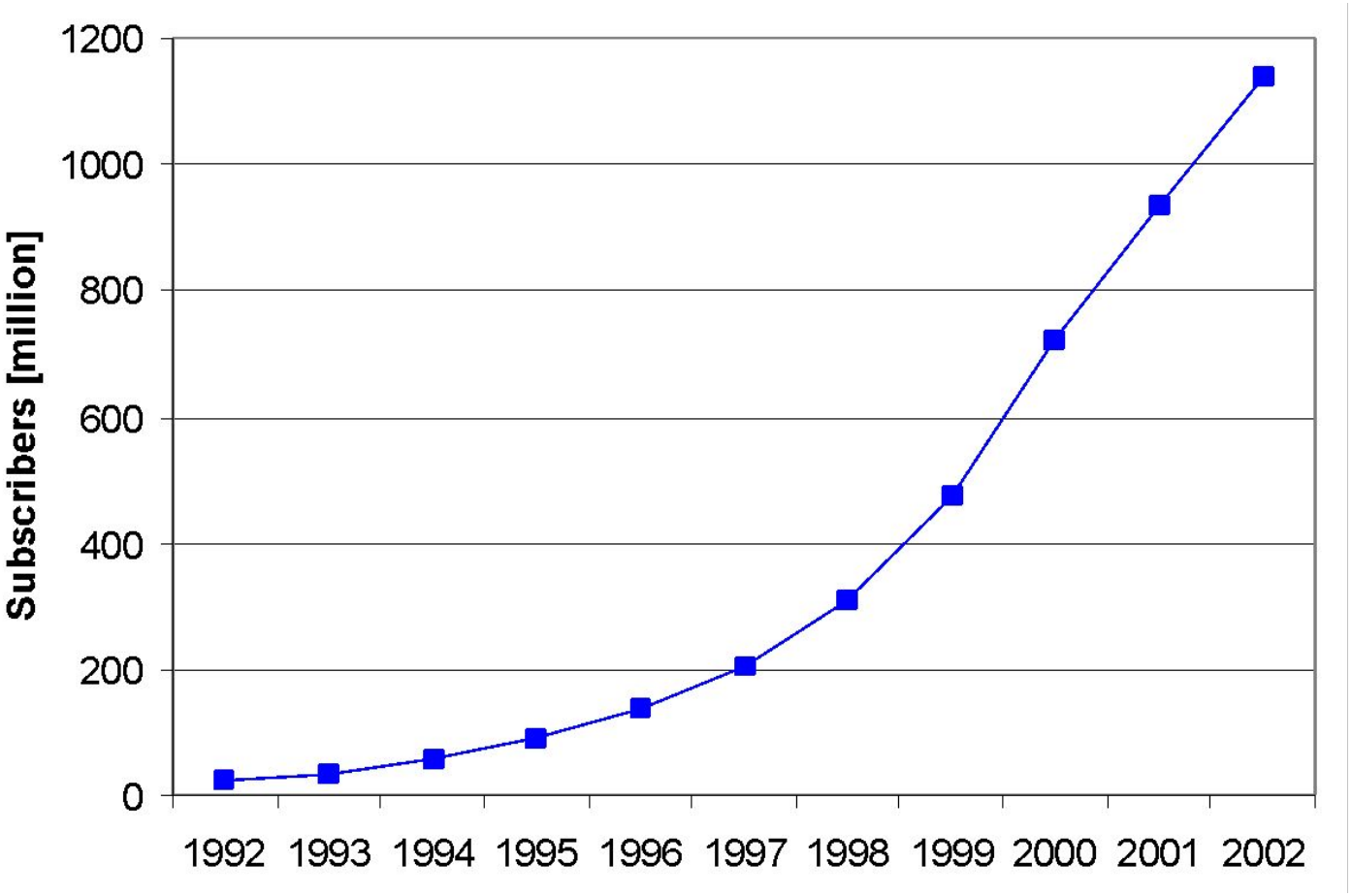


Mobile phones per 100 people 1999



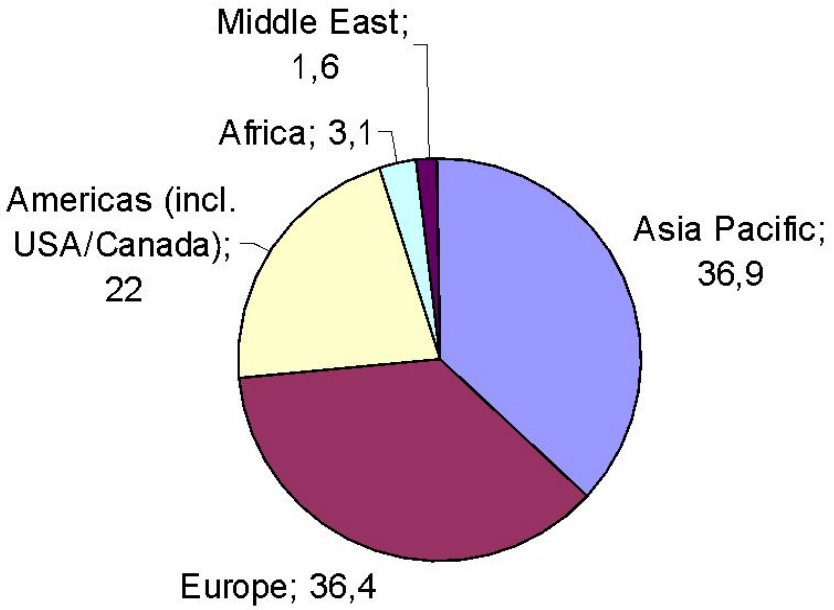
2005: 70-90% penetration in Western Europe

Worldwide cellular subscriber growth



Note that the curve starts to flatten in 2000 – 2004: 1.5 billion users

Cellular subscribers per region (June 2002)



2004: 715 million mobile phones delivered

Mobile statistics snapshot (09/2002 / 12/2004)

Total Global Mobile Users
869M / 1.52bn
Total Analogue Users 71M / 34m
Total US Mobile users 145M / 140m
Total Global GSM users 680M / 1.25T
Total Global CDMA Users 127M / 202m
Total TDMA users 84M / 120m
Total European users 283M / 343m
Total African users 18.5M / 53m
Total 3G users 130M / 130m(?)
Total South African users 13.2m / 19m
European Prepaid Penetration 63%
European Mobile Penetration 70.2%
Global Phone Shipments 2001 393m
Global Phone Sales 2Q02 96.7m

http://www.cellular.co.za/stats/stats-main.htm

#1 Mobile Country China (139M / 300m)
#1 GSM Country China (99m)
#1 SMS Country Philipines
#1 Handset Vendor 2Q02 Nokia (37.2%)
#1 Network In Africa Vodacom (6.6m)
#1 Network In Asia Unicom (153m)
#1 Network In Japan DoCoMo
#1 Network In Europe T-Mobile (22m / 28m)
#1 In Infrastructure Ericsson
SMS Sent Globally 1Q02 60T / 135bn
SMS sent in UK 6/02 1.3T / 2.1bn
SMS sent Germany 1Q02 5.7T
GSM Countries on Air 171 / 210
GSM Association members 574 / 839
Total Cost of 3G Licenses in Europe 110T€
SMS/month/user 36

The figures vary a lot depending on the statistic, creator of the statistic etc.!

Areas of research in mobile communication

Wireless Communication

- transmission quality (bandwidth, error rate, delay)
- modulation, coding, interference
- media access, regulations
- ...

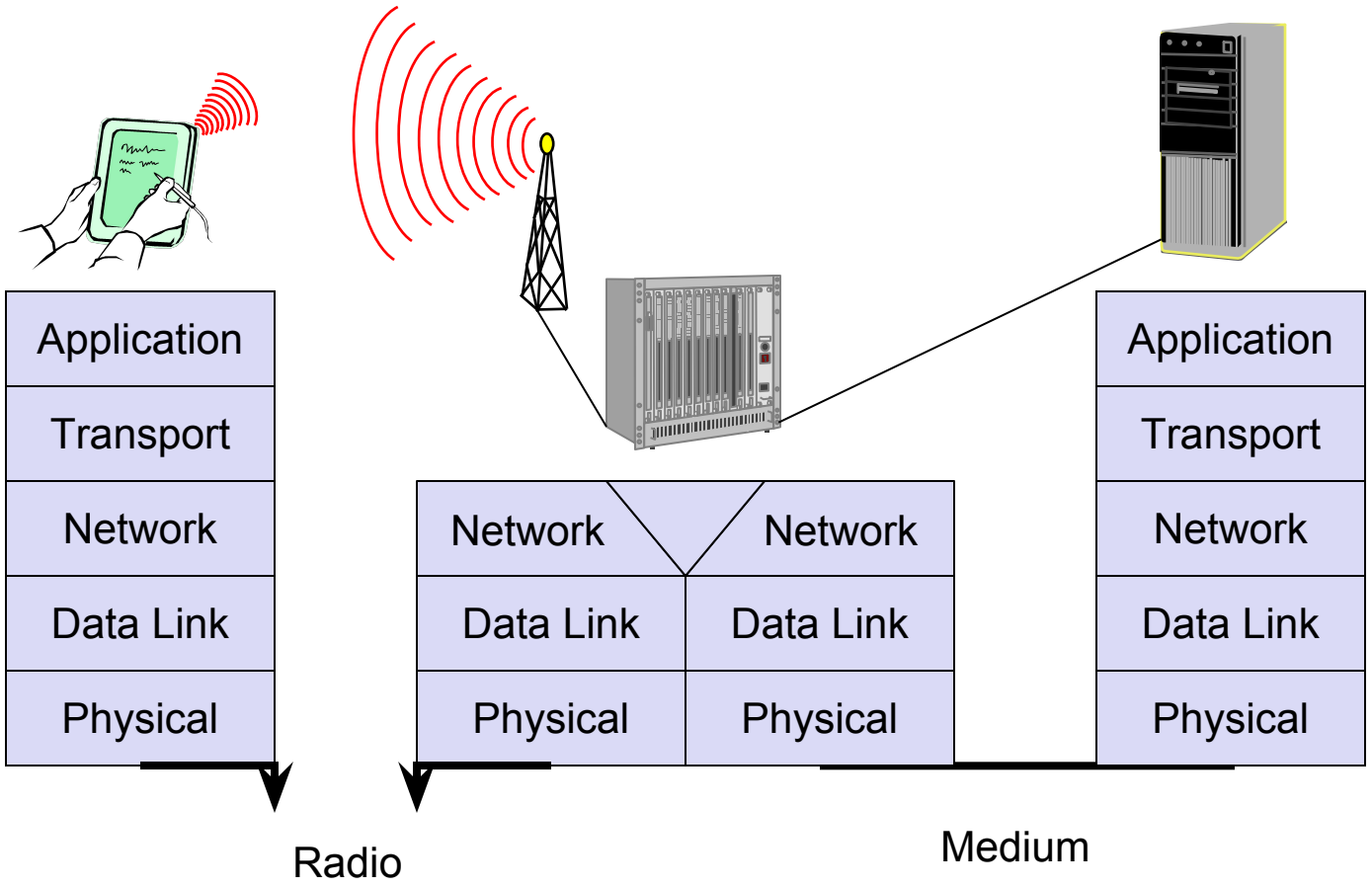
Mobility

- location dependent services
- location transparency
- quality of service support (delay, jitter, security)
- ...

Portability

- power consumption
- limited computing power, sizes of display, ...
- usability
- ...

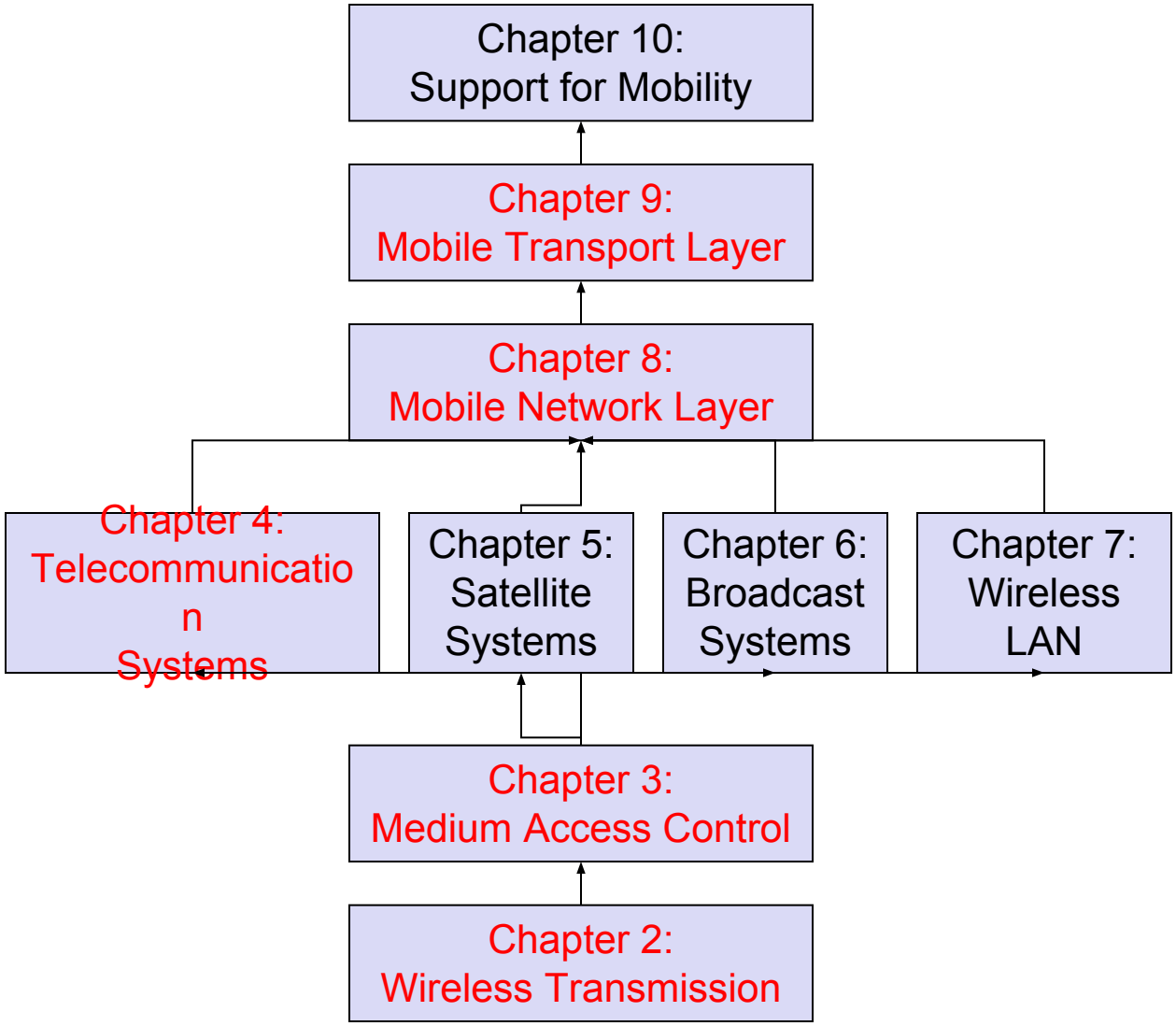
Simple reference model used here



Influence of mobile communication to the layer model

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
Data link layer	❑ authentication ❑ media access ❑ multiplexing ❑ media access control
Physical layer	❑ encryption ❑ modulation ❑ interference ❑ attenuation ❑ frequency

Overview of the main chapters



Overlay Networks - the global goal

integration of heterogeneous fixed and mobile networks with varying transmission characteristics