Mobile Communications

https://www.cs.tcd.ie/courses/baict/bass/4ict9/

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The Fundamentals

- ✓ Signal, path, signal effects (noise, multipath, propagation etc)
- ✓ Antenna and signal multiplexing
- ✓ Modulation/Medium Access/Spread Spectrum
- ✓ Network Planning
- ✓ Mobile Telecommunications (GSM, GPRS, 3G, 4G, Beyond 4G)
- ✓ Convergence
- ✓ Wireless LANs, PANs, MANs
- ✓ Network Positioning
- ✓ Location Based Services
- ✓ Ubiquitous computing
- ✓ Sensornets
- ✓ Ethics and the Dark Side
- ✓ Security

You decide……

Lab Work

- ✓ Lab 1: Network Planning in Action (7%)
  - ✓ To be given out on 20th October
  - ✓ To be presented/demonstrated on 10th November
- ✓ Lab 2: Network Planning Tools (6%)
  - ✓ To be given out on 18th November
  - ✓ To be presented/demonstrated on 8th December
- ✓ Lab 3: Implementation of Practical Location Based Services (7%)
  - ✓ Will take 4 to 5 weeks in Hillary Term

Lectures, Notes, Reading Material etc

- ✓ No assigned book
- ✓ You may find “Mobile Communications”, Jochen Schiller, Addison Wesley useful for background reading (and we acknowledge the authorship and thank Herr. Prof. Dr. Schiller for the use of his excellent ppt slides for some of this course). There are some copies of this book available in the Hamilton Library.
- ✓ There will be prescribed readings for this course taken from relevant publications in the area. Check the web page for each course and make notes in class on what you need to know.
- ✓ See the course webpage for information on the provisional lecture schedule etc (https://www.cs.tcd.ie/courses/baict/bass/4ict9/)

Mobile Communications

A Brief Introduction

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)

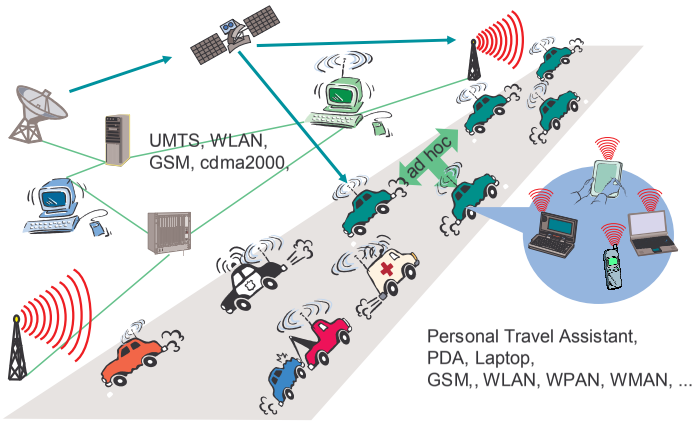
The demand for mobile communication creates the need for integration of wireless networks into existing fixed networks:
- local area networks: standardization of IEEE 802.11, ETSI (HIPERLAN)
- Internet: Mobile IP extension of the internet protocol IP
- wide area networks: e.g., internetworking of GSM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

Applications I

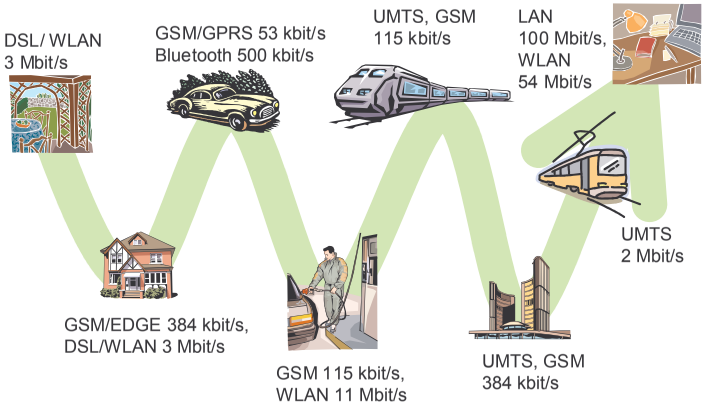
Vehicles
- transmission of news, road condition, weather, music via DAB
- personal communication using GSM
- position via GPS
- local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
- vehicle data (e.g., from busses, high-speed trains) can be transmitted in advance 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

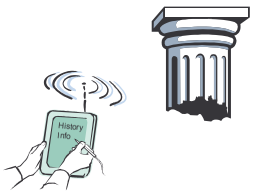


Applications II

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.scatterweb.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

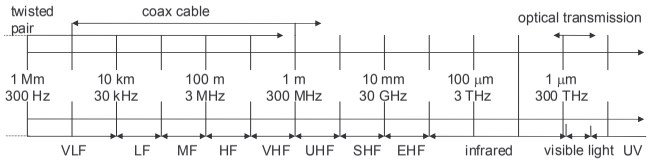
Low transmission rates
- local some Mbit/s, regional currently, e.g., 53kbit/s with GSM/GPRS

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

Frequencies for communication



VLF = Very Low Frequency
LF = Low Frequency
MF = Medium Frequency
HF = High Frequency
VHF = Very High Frequency
UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extra High Frequency
UV = Ultraviolet Light

Frequency and wave length:

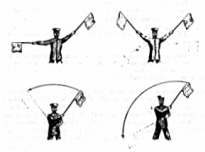
$\lambda = c/f$

wave length λ, speed of light $c \cong 3x10^8 m/s$, frequency f

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,)

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, …

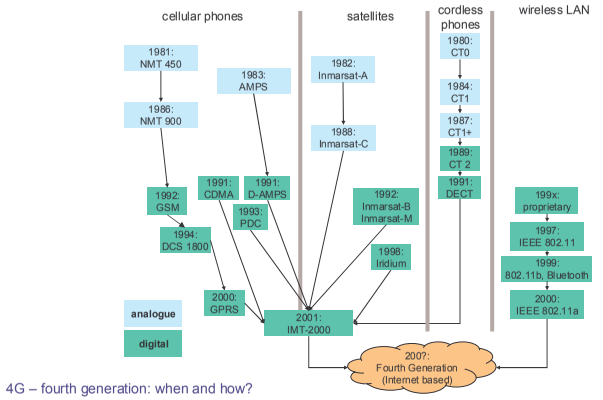
Start of WAP (Wireless Application Protocol) and i-mode
- First step towards a unified Internet/mobile communicaiton system
- Access to many services via the mobile phone

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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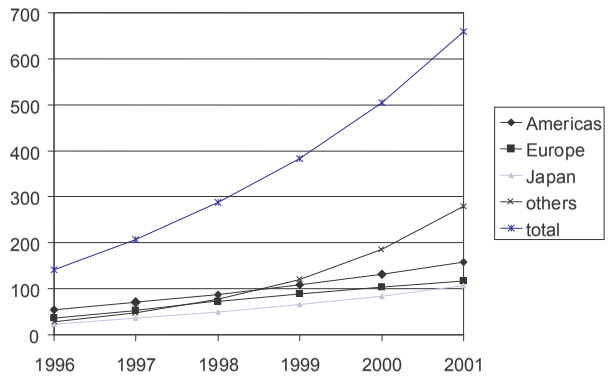
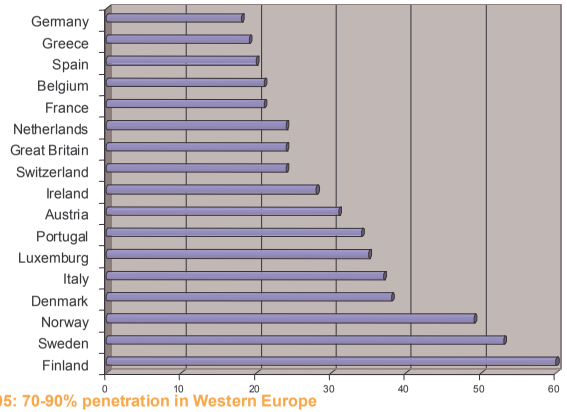
http://www.itu.int/imt

Worldwide wireless subscribers (old prediction 1998)

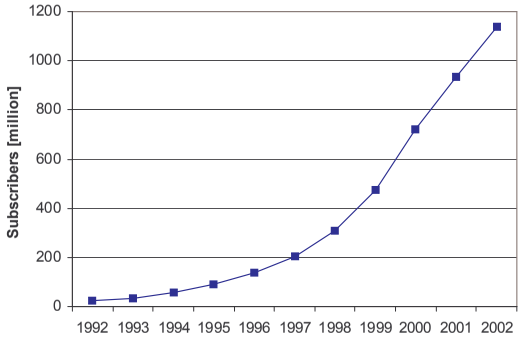


Mobile phones per 100 people 1999



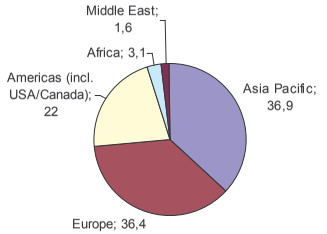
2005: 70-90% penetration in Western Europe

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.!

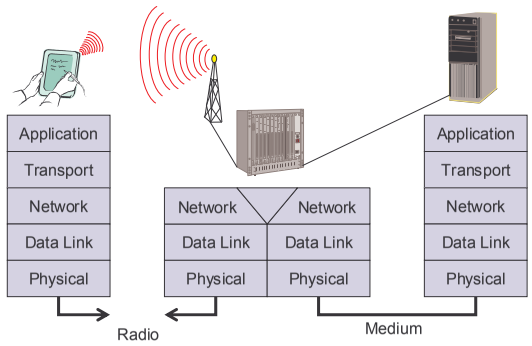
Areas of research in mobile communication

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
- ...

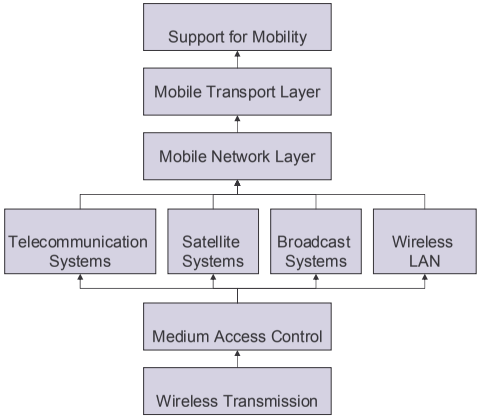
Simple reference model used here



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 Topics we Consider



Overlay Networks - the global goal

integration of heterogeneous fixed and mobile networks with varying transmission characteristics