Mobilkommunikation - Mobile Communications

Lecture 1: Scope

Prof. Dr.-Ing. Markus Fidler

Institute of Communications Technology
Leibniz Universität Hannover

April 8, 2016

Outline

Schedule

Lecture (TV2)

- Friday 09:00-10:30
- Room iL2 (1514), Appelstr. 9a, 15th floor
- April 8 - July 15, 2016 except for
  - May 6 (Bridging day after Ascension Day)
  - June 20 (Pentecost, excursion week)
- Course cycle: Each summer term

Exercise (Ü1)

- Instructor: Dipl.-Ing. Felix Langenbruch
- Friday 10:45-11:30
- Room iL2 (1514), Appelstr. 9a, 15th floor
- Start: April 15

Exam and consultation hours

Exam

- Written, 90 minutes
- Only the lecture/exercise are relevant for the exam
- Usually 4 credit points unless specified otherwise in your examination regulations

Consultation hours

- On demand
- Instructor: Dipl.-Ing. Felix Langenbruch
- Room 1436

General information

Prerequisites

- Lecture Networks and Protocols (Netze und Protokolle) or
- Lecture Computer Networks (Rechnernetze)

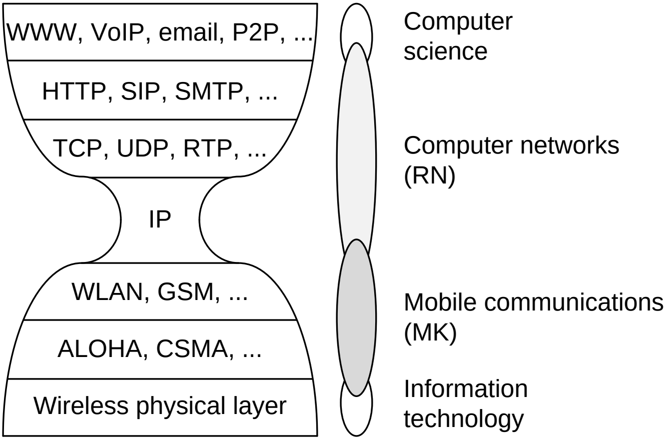
References and further reading

- References to current literature will be provided in the lecture
- Further reading is optional
- Attending the lecture and taking notes is beneficial
- Course material will be provided on the Stud.IP course page `https://elearning.uni-hannover.de`

Most of this course is also covered by the textbook

- Jochen Schiller, Mobile Communications, Second Edition, Addison-Wesley, 2003.

Overview



'Wireless' Internet hourglass

Related courses in information technology

- Modulation Processes (Modulationsverfahren), SoSe
  Prof. Peissig, Institute for Communications Technology (IKT)
- Digital communications technologies (Digitale Nachrichtenübertragung), WiSe
  Prof. Peissig, Institute for Communications Technology (IKT)
- Information Theory (Informationstheorie), SoSe
  Prof. Ostermann, Information Technology Laboratory (TNT)
- Channel Coding (Kanalcodierung), SoSe
  Prof. Ostermann, Information Technology Laboratory (TNT)
- Source Coding (Quellencodierung), WiSe
  Prof. Ostermann, Information Technology Laboratory (TNT)

Related courses in communications networks

Lectures

- Networks and Protocols (Netze und Protokolle), WiSe
- Teletraffic Theory (Nachrichtenverkehstheorie), WiSe
- Computer Networks (Rechnernetze), SoSe
- Future Internet, Prof. Papadimitriou, SoSe
- Network Management, Prof. Papadimitriou, WiSe
- Cognitive Radio Networks (Kognitive Funknetzwerke), Dr. Pérez, WiSe
- 3G/4G Evolution, block course, Dr. Steuer, WiSe

Labs

- Networks and Protocols (Netze und Protokolle), SoSe
- Computer Networks (Labor: Rechnernetze), WiSe

Some related research projects at the Institute of Communications Technology offer interesting topics final thesis as well as Hiwi jobs

- Social Cars, DFG Graduate School

  Car-2-X communications using WLAN, as well as GSM, LTE

- UnIQue - Towards a Unified Information and Queueing Theory, ERC Starting Grant

  Quality of service of wireless networks

Institut für Kommunikations-Technik

Organization

Scope of the lecture

Introduction
- History
- Radio spectrum

Leibniz Universität Hannover

Vision

The goal is to facilitate

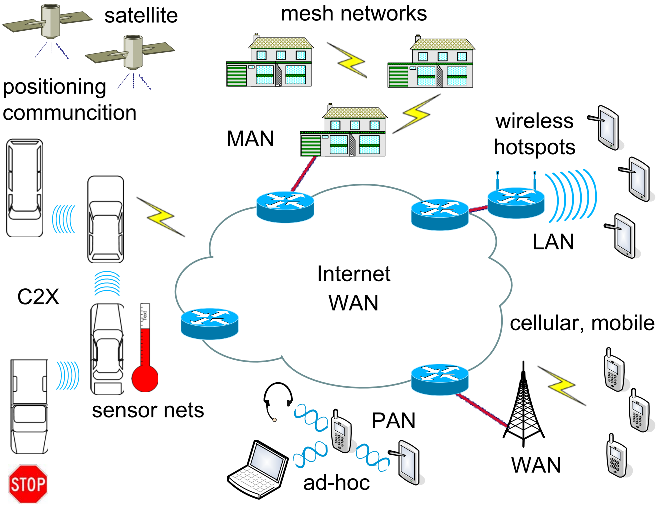
- seamless wireless communications,
  - anywhere, anytime
  - office, home, campus, ...
  - plane, train, car, ...
  - among devices, ...

Vision

The goal is to facilitate

- seamless wireless communications,
  - anywhere, anytime
  - office, home, campus, ...
  - plane, train, car, ...
  - among devices, ...
- always best connected
  - quality of service
    - data rate
    - delay
    - delay jitter
  - dependability
    - availability
    - reliability
    - security
  - cost

Applications



Challenges

Wireless communication differs significantly from wired communication, causing considerable challenges

- interference
- regulations and spectrum
- low quality of service, i.e.
  - low bandwidth
  - high delays
  - high delay variation
- lower security, simpler to attack
- shared medium, simple denial of service attacks
- ad-hoc networking, multi-hop wireless communication
- efficient spectrum use, cognitive radio networks

Spatial classification

Classification by spatial dimension of communication

- **PAN:** Personal Area Network
  - devices close to one person in a range of a few meters
  - e.g. Bluetooth, ZigBee, UWB
- **LAN:** Local Area Network
  - local area at home, at the office, or between buildings
  - e.g. WLAN, HiperLAN
- **MAN:** Metropolitan Area Network
  - larger geographical area among several houses up to entire cities
  - e.g. WiMAX
- **WAN:** Wide Area Network
  - broad area beyond metropolitan, regional, or national boundaries
  - e.g. GSM, GPRS, EDGE, UMTS, CDMA, LTE

Classification by mobility

Types of mobility

- **User mobility:** User has access to the same services at different places, e.g. call forwarding
- **Device mobility:** Device moves, e.g. mobile phone

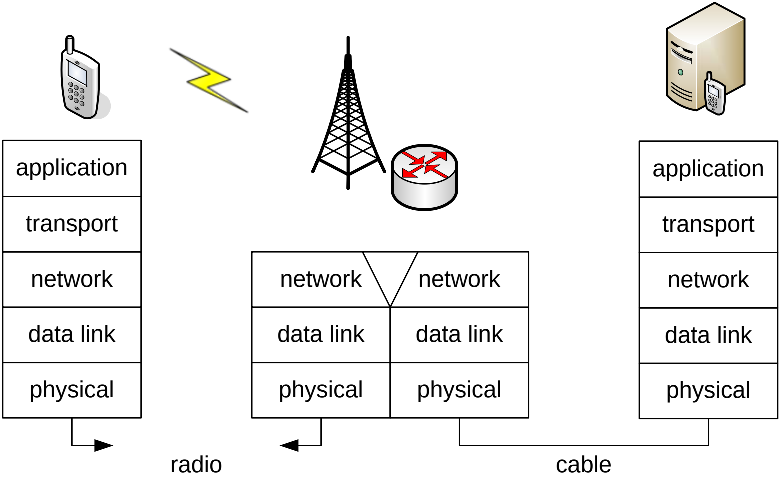
Characteristics of a communication device

- **Fixed and wired:** E.g. desktop PC with Ethernet connection
- **Mobile and wired:** E.g. laptop connected via Ethernet or modem dial-up line
- **Fixed and wireless:** E.g. desktop PC with WLAN, or WiMAX as a DSL substitute
- **Mobile and wireless:** E.g. laptop with UMTS card

Reference model

- **Physical layer:** conversion of bit streams into signals that are transmitted, involves channel coding, frequency selection, modulation, and signal detection at the receiver
- **Data link layer:** medium access and multiplexing of data streams, frame synchronization, correction of transmission errors to establish reliable point-to-(multi)point connections
- **Network layer:** connection establishment, routing of packets over a number of intermediate systems involving addressing, device location, handover between networks or base stations
- **Transport layer:** establish and maintain an end-to-end connection with flow and congestion control and a certain quality of service
- **Application layer:** support of different applications and their requirements in wireless and mobile communications

Reference model continued

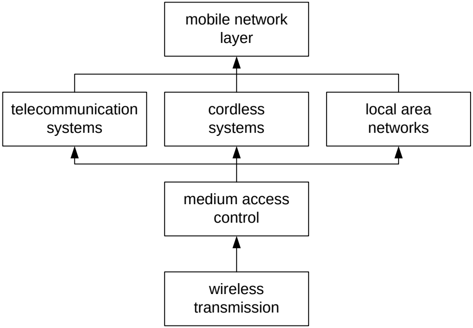


Basics in bottom-up order

- wireless transmission
- medium access control

Radio systems

- telecommunications
  - GSM
  - UMTS
  - LTE
- cordless systems
  - DECT
- local area networks
  - Wifi
  - Bluetooth



Lecture philosophy

Scope: wireless and mobile communications

- a multiplicity of standards for wireless communications exists
  - e.g. GSM, GPRS, EDGE, UMTS, LTE, CDMA, Inmarsat, Iridium, WiMAX, DECT, WLAN, HiperLAN, Bluetooth, ZigBee, UWB, ...
  - a single course cannot deal with all of these and
  - it is not meaningful to deal with all of these
- the different standards have many differences but all
  - face similar challenges
  - rely on the same principles
- focus of this lecture is first on basics of wireless and mobile communications
- afterwards details are given on a few selected and widely used standards

Topics of the lecture

Wireless and mobile communications

- organization, scope, and introduction
- physical layer, wireless transmission
  - characteristics of radio communications
  - modulation, multiplexing
  - cellular communications
- data link layer, medium access control
  - frequency, time, and code division multiple access
  - Aloha, slotted Aloha
  - carrier sense multiple access
- local area networks
- personal area networks
- telecommunication systems
- mobile network layer

Outline

History

Wireless communication has a long history, many early methods are still used today

- smoke signals
- fires, often even with relaying, i.e. multi-hop communications
- light signals
- flags
- optical telegraph (1794)

Based on seminal works on electromagnetic waves by Faraday, Maxwell, and Hertz, radio telegraphy is first demonstrated by Marconi in 1895. In 1920 Marconi discovers short waves.

History of digital radio communications

- 1982 start of GSM specification (Internet 500 hosts)
  - goal is a pan-European system with roaming
- 1991 specification of DECT (Internet 0.6M hosts)
  - cordless telephony up to 100-500 meters range
- 1992 start of GSM (WWW Mosaic '93, Internet 1M hosts)
  - 900 Mhz and later also 1800 Mhz with 9.6 kb/s data rate
  - cellular system with automatic location, handover, and roaming
- 1997 wireless LAN IEEE 802.11 (Internet $>$ 16M hosts)
  - 2.4 GHz with 2 Mb/s
- 1998 specification of GSM sucessors, 3G UMTS
- 1998 start of Iridium satellite telephony
- 1999 wireless LAN IEEE 802.11b
  - 2.4 GHz with 11 Mb/s
- 2000 GSM circuit and packet data (Internet $>$ 300M hosts)
  - HSCSD 115.2 kb/s, GPRS 171.2 kb/s, EDGE 473.6 kb/s

Recent development

- 2000 3G (UMTS) auctions in Germany
  - hype ($98 \cdot 10^9$ €) followed by disillusionment
- 2001 wireless LAN IEEE 802.11a
  - 5 GHz with 54 Mb/s
- 2003 wireless LAN IEEE 802.11g
  - 2.4 GHz with 54 Mb/s
- 2004 start of 3G in Germany
  - HSDPA downlink 14.4 Mb/s
- 2009 wireless LAN IEEE 802.11n
  - 2.4 or 5 GHz with 600 Mb/s using MIMO (4×4) spatial multiplex and channel bonding (2×20 MHz)
- 2011 4G LTE
  - up to 300 Mb/s downlink, 75 Mb/s uplink
- 2013 wireless LAN IEEE 802.11ac
  - 5 GHz, Gigabit Wifi, MIMO (8×8) spatial multiplex, channel bonding (8×20 MHz)
- Currently 5G research and standardization

Standardization and market forces

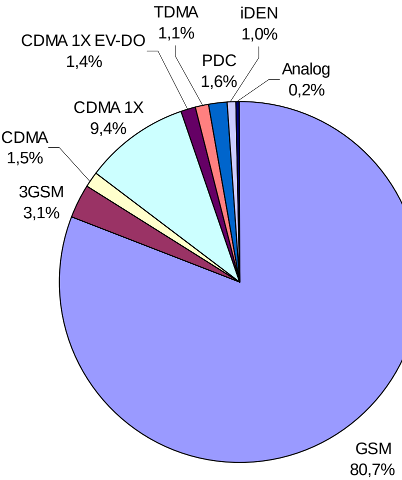
The USA rely on open competition and market forces to select a certain technology

- the approach is highly successful in the context of the Internet possibly due to the availability of cheap equipment, e.g. IEEE 802.11 WLAN
- in the area of telecommunication networks it created, however, a number of parallel, competing, and not interoperable cellular mobile networks

In contrast Europe relies heavily on standardization

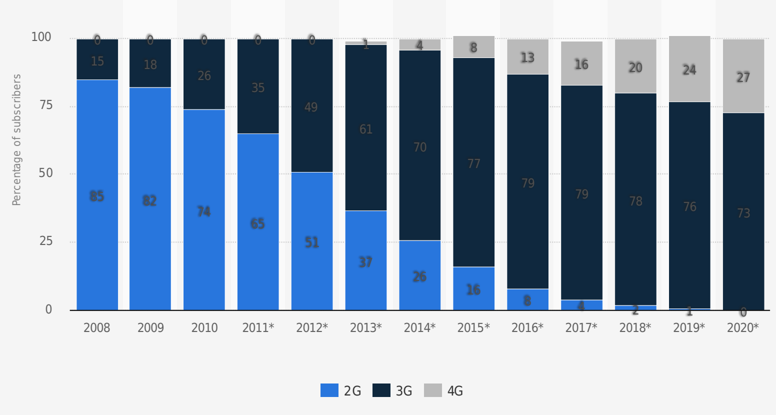
- the approach is highly successful in telecommunication networks possibly due to the complexity, e.g. GSM and subsequent evolution
- it is, however, not successful in data networks and the Internet, e.g. Hiperlan did not see wide use

Subscribers by technology



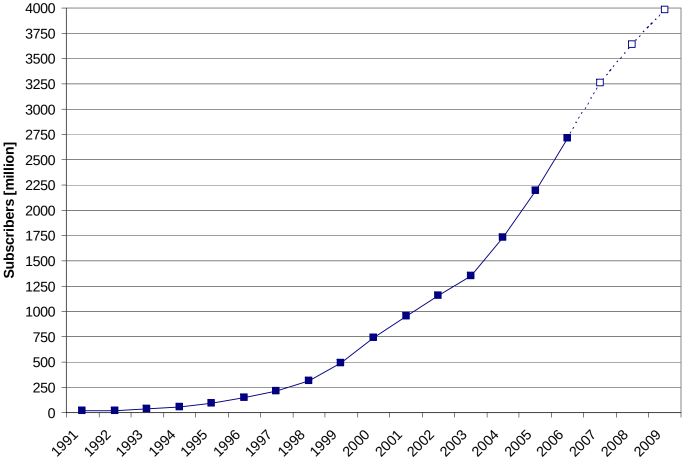
Source: Wireless Intelligence, 2006

Subscribers by technology



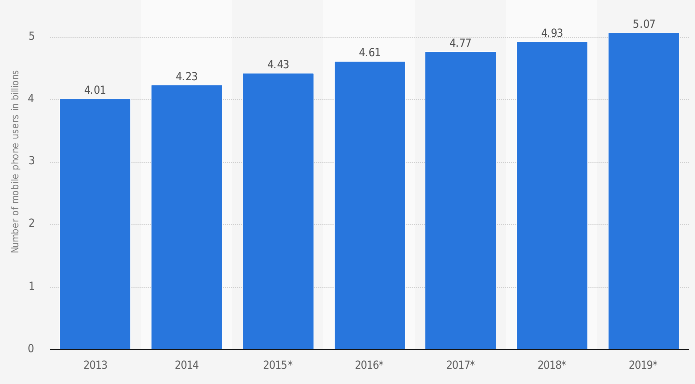
Source: statista, 2011

Overall subscribers



Source: Informa Telecoms & Media's World Cellular Information Service, 2006

Overall subscribers

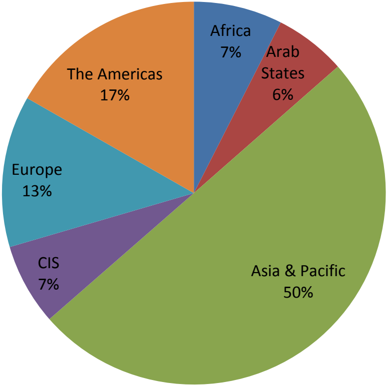


Source: statista, 2014, 60% of the population worldwide own a phone

Source: GSMA intelligence, April 2016

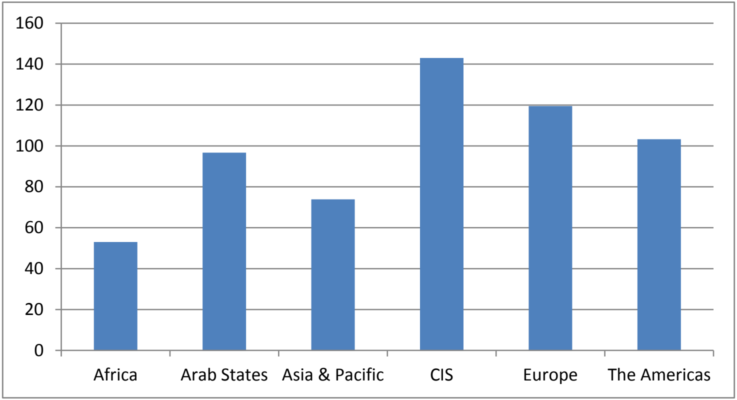
- 4.7 billion unique mobile subscribers
- 7.7 billion mobile connections including machine-to-machine

Subscriptions by region



Source: ITU, Nov. 2011

Subscriptions per one hundred people



Source: ITU, Nov. 2011

Major phone manufacturers

Mobile phone vendors (million handsets in 2012, Source: Gartner)

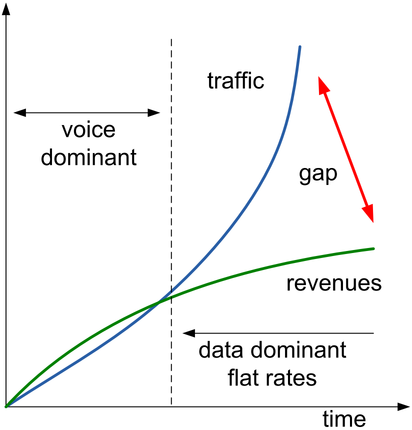
- Samsung 384.6
- Nokia 333.9
- Apple 130.1
- ZTE 76.9
- LG 58
- Huawei 47.3
- TCL 37.2
- BlackBerry 34.2
- Motorola 33.9
- HTC 32.1
- Others 587.4
- Total 1746.2

497.1 Android, 135.9 iOS of 722.4 smartphones (Source: IDC)

Major network operators

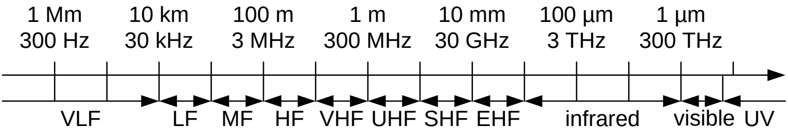
Network operators (million subscribers in 2010, Source: Portio)

- China Mobile (China) 594.2
- Vodafone (UK) 338.9
- America Movil (Mexico) 224.4
- Telefonica (Spain) 216.9
- Bharti Airtel (India) 199.2
- China Unicom (China) 169.3
- AT&T (US) 148.8
- SingTel (Singapore) 133.9
- France Telecom (France) 129.5
- Reliance Communications (India) 125.7



Source: Next Generation Mobile Networks

Spectrum



The spectrum is divided into low, medium, and high frequency (very, ultra, super, extremely) followed by light.

The wave length is given by the relation

$$\lambda = c/f$$

where

- $c =$ speed of light, in free space $c = 3 \cdot 10^8$ m/s
- $f =$ carrier frequency

Frequency bands for mobile communication

- VHF-/UHF-ranges for mobile radio
  - simple, small antennas for cars
  - good propagation characteristics, reliable connections
- SHF and higher for directed radio links, satellite communication
  - small antenna, focusing the transmitted signal
  - high bandwidth available
- wireless LAN/MANs use frequencies in UHF to SHF spectrum
  - some systems planned up to EHF
  - limitations due to absorption by water and oxygen molecules (resonance frequencies)
  - weather dependent fading, signal loss caused by heavy rainfall etc.

Some allocated frequency bands in Europe

The radio spectrum is a scarce resource that is highly fragmented.

Band	MHz	MHz
LTE	791	821
	832	862
GSM	880	915
	935	960
DCS	1710	1785
	1805	1880
DECT	1880	1900
UMTS TDD	1900	1920
	2010	2025
UMTS FDD	1920	1980
	2110	2190
ISM	2400	2483
LTE	2500	2570
	2620	2690

ISM stands for Industrial, Scientific, and Medical. The ISM band at 2.4 GHz is used by many technologies, e.g. WLAN, Bluetooth, etc.

Regulation and standardization bodies

The Radio sector of the International Telecommunications Union (ITU-R) handles standardization and frequency planning:

- Region 1: Europe, Middle East, former Soviet Union, Africa
- Region 2: Greenland, North and South America
- Region 3: Far East, Australia, New Zealand

In Europe the European Telecommunications Standards Institute (ETSI) takes care of standardization.

ETSI is one of five members of the 3rd Generation Partnership Project (3GPP) that is a worldwide standardization cooperation.

Last but not least, the Institute of Electrical and Electronics Engineers (IEEE) contributes significant standards.

Literature

- Jochen Schiller, Mobile Communications, Second Edition, Addison-Wesley, 2003.
- Vijay Garg, Wireless Communications & Networking, Morgan Kaufmann, 2007.
- Matthias Hollick, Communication Networks 3 - Mobile Communications, TU Darmstadt, 2008.