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**Humboldt-Universität zu Berlin, Institut für Informatik,  
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Vorlesung Drahtlose Breitbandkommunikationssysteme

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## Literatur/Quellen

- Jochen Schiller: Mobilkommunikation  
Addison-Wesley ISBN 3-8273-1578-6  
(es gibt eine neue Auflage!)
- Matthew Gast: 802.11 Wireless Networks  
O'Reilly ISBN 0-596-00183-5
- Bernhard Walke: Mobilfunknetze und ihre Protokolle  
Band 1  
Teubner Verlag ISBN 3-519-06430-8
- Bernhard Walke: Mobilfunknetze und ihre Protokolle  
Band 2  
Teubner Verlag ISBN 3-519-06431-6
- Klaus David: Digital Mobilfunksysteme  
Teubner Verlag ISBN 3-519-06181-3

## Breitbandkommunikation - Einführung

- Bei der **Breitbandkommunikation** führen die **Kanaleigenschaften** von Leitungs- oder Funkverbindungen zu verschiedenen Beeinträchtigungen der seriell übertragenen Symbole.
- Dazu gehören *Rauschen*, *Dämpfung* und *Intersymbol Interferenz*. Diese Beeinträchtigungen können durch geeignete **Übertragungs- und Signalverarbeitungsverfahren** weitestgehend korrigiert werden.
- Besonderer Fokus liegt dabei auf modernen **drahtlosen Hochgeschwindigkeitsnetzwerken**, die dem Anwender zukünftig Übertragungsraten von über 1(10) Gbit/s zur Verfügung stellen.

### Lehrinhalte

1. Einführung, Besonderheiten der drahtlosen Übertragung
2. Kanaleigenschaften und Kanalmodelle
3. Modulationsverfahren
4. Kanalcodierung und Fehlerkorrekturverfahren
5. Synchronisation und Kanalschätzung
6. Implementierungsaspekte

## Breitbandkommunikation - Einführung

### Was ist Breitbandkommunikation?

- Digitale Breitbandkommunikation bezeichnet in Deutschland Übertragungsgeschwindigkeiten oberhalb von 128 kBit/s. Die Europäische Union und die ITU sprechen ab 2 Mbit/s von Breitband - *veraltet!*
- Breitbandkommunikation Brockhaus (2008) „Transfer oder Austausch von Informationen über Systeme zur Datenübertragung mit einer Bandbreite von [...] mindestens 2 MBit/s“.
- Breitbandkommunikation (Wikipedia) Breitbandig (Broadband) bedeutet, dass die Symboldauer  $T_s$  nicht bedeutend größer ist als die maximale Verzögerung  $t_{\max}$  eines Signals.

### IHP-Forschung:

- 30 Gbit/s über (kurze) Kupferleitungen
- 160 Gbit/s über (lange) optische Glasfaserleitungen
- 1 .. 10(0) Gbit/s drahtlos über (kurze) Funkstrecken

## Breitbandkommunikation - Einführung

### 1. Festnetz (Fixed-Line-Access)

- Digitale Festverbindungen: 1000 Mbit/s -> 40 Gbit/s (Optical)
- Digital-Subscriber-Line (DSL): 1 bis 16 Mbit/s -> 52 Mbit/s (VDSL)
- Powerline: Anschluss über das Stromkabel, 10 .. 200 Mbit/s, -> 500 Mbit/s
- Internet via TV-Kabel: 2 bis 100 Mbit/s
- Fibre-To-The-Home (FTTH): Glasfaserbasierter Kundenanschluss  
10..1000 Mbit/s

### 2. (LAN, MAN) Funknetz (Fixed-Radio-Access)

- **Wireless-Local-Area-Network (W-LAN): 11 Mbit/s oder 54 Mbit/s (300 Mb/s)**  
-> bis 10 Gbit/s

### 3. Mobilfunk (Mobile-Radio-Access)

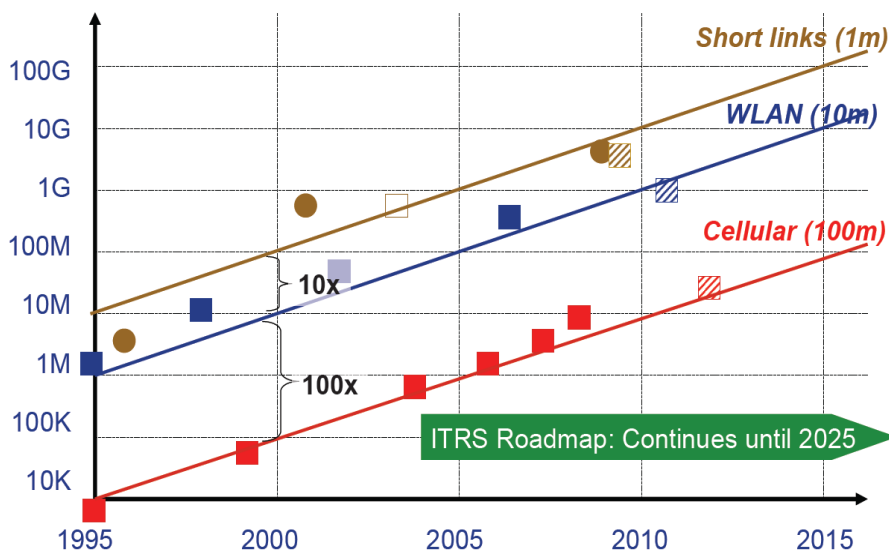
- Universal Mobile Telecommunications System (UMTS): 384 kbit/s -> 7 Mbit/s
- LTE: 326 Mbit/s (4x4 MIMO); 172 Mbit/s (2x2 MIMO); 120 Mbit/s (realistic)
- LTE-Advanced: 1 Gbit/s (<10 km/h); 100Mbit/s (<350 km/h)

### 4. Satellit

- Down: 768 kbit/s bis 16 Mbit/s, Up: oftmals per Telefonanschluss

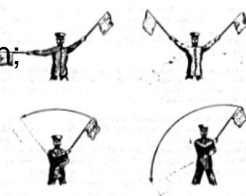
z.T. aus: Jan Marco Leimeister, Marina Berkovich: Breitbandkommunikation; Wikipedia

## Wireless Systems Roadmap (Source G. Fettweis)



## 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
- Electromagnetic waves are of special interest and 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!, UWB pulstransmission)
  - Long wave transmission, high transmission power necessary (> 200 kW); large antennas!
- 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, 160 MHz, connection setup only from the mobile station, no handover, 80 % coverage, 1971: 11000 customers in Germany
- 1972 B-Netz in Germany
  - analog, 160 MHz, 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 Germany
- 1979 NMT (Nordic Mobile Telephone); Analog at 450 MHz (later 900 MHz) in 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; analog cordless telephone standard that was defined by the European Conference of Postal and Telecommunications Administrations (CEPT); 915/960 MHz

## History of wireless communication III

- 1986 C-Netz in Germany
  - analog voice transmission, 450 MHz, hand-over possible, digital signaling, automatic location of mobile device
  - Was in use until 2000, services: FAX, modem, X.25, e-mail, 98 % coverage
- 1988 first discussion of UMTS networks as a solution of a worldwide wireless communication system (later known as „IMT-2000“)
- 1991 Specification of DECT
  - Digital European Cordless Telephone (today: Digital Enhanced Cordless Telecommunications)
  - 1880 – 1900 MHz, ~100 – 500 m range, 120 duplex channels, 1.2 Mbit/s data transmission, voice encryption, authentication, up to several 10000 user/km<sup>2</sup>, used in more than 50 countries
- 1992 Start of GSM commercial operation
  - in Germany as D1 and D2, fully digital, 900 MHz, 124 channels
  - automatic location, hand-over, cellular
  - roaming in Europe - now worldwide in more than 200 countries
  - services: data with 9.6 kbit/s, FAX, voice, ...

## History of wireless communication IV

- 1994 E-Netz in Germany
  - GSM with 1800 MHz, smaller cells
    - As E-Plus in Germany (1997 98 % coverage of the population)
- 1996 HiperLAN (High Performance Radio Local Area Network)
  - ETSI, standardization of type 1: 5.15 - 5.30 GHz, 23.5 Mbit/s
    - recommendations for type 2 and 3 (both 5 GHz) and 4 (17 GHz) as wireless ATM-networks (up to 155 Mbit/s)
- 1997 Wireless LAN - IEEE802.11
  - IEEE standard, 2.4 - 2.5 GHz and infrared, 2 Mbit/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
- 1998 Iridium
  - 66 satellites (+6 spare), 1.6 GHz to the mobile phone

## History of wireless communication V

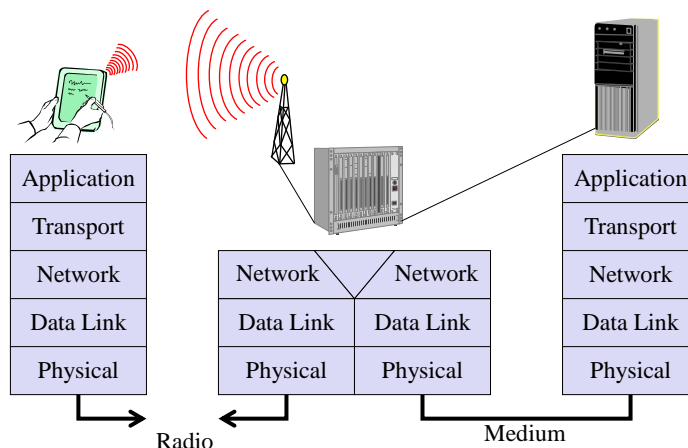
- 1999 Standardization of additional wireless LANs
  - IEEE standard 802.11b, 2.4 - 2.5 GHz, 11 Mbit/s
  - Bluetooth for piconets, 2.4 GHz, < 1 Mbit/s
- Start of WAP (Wireless Application Protocol) and i-mode
  - First step towards a unified Internet/mobile communication system
  - Access to many services via the mobile phone
- 2000 GSM with higher data rates
  - HSCSD offers up to 57.6 kbit/s
  - First GPRS trials with up to 50 kbit/s (packet oriented!)
- UMTS auctions/beauty contests
  - Hype followed by disillusionment (100 B DM paid in Germany for 6 licenses!)
- 2001 Start of 3G systems
  - CDMA 2000 in Korea, UMTS tests in Europe, Foma (almost UMTS) in Japan
- 2006 IEEE 802.11n (600 Mbit/s for 4x4 MIMO); 300 Mbit/s realistic
- 2008 IEEE 802.15.3c WPAN Standard (60 GHz); 6 Gbit/s (Wireless HDMI)
- 2010 Roll out of first LTE systems in Germany
- 2012 IEEE802.11ac; IEEE802.11ad

## Areas of research in mobile communication

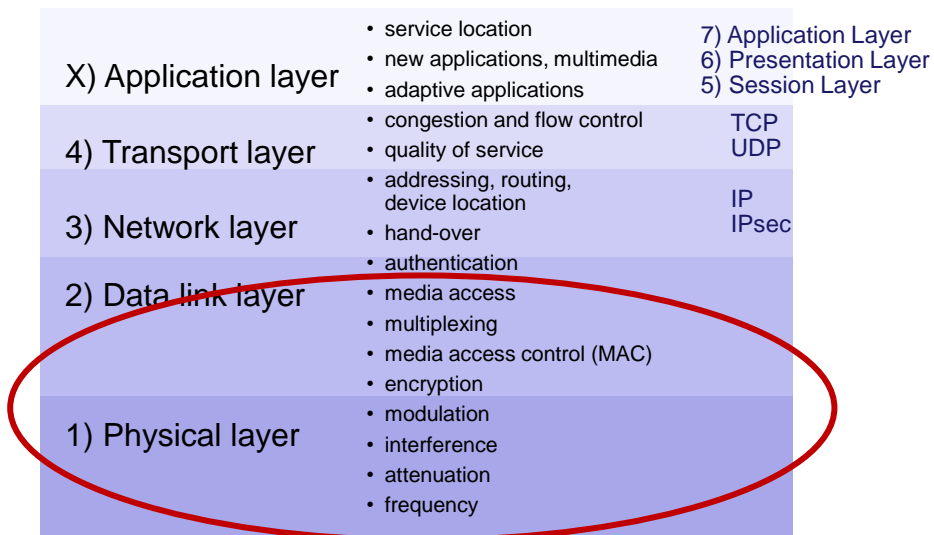
- **Wireless Communication**
  - transmission quality (bandwidth, error rate, delay)
  - modulation, coding, interference
  - media access, regulations
  - Security and reliability
  - Reduction of latency ("tactile internet") ...
- **Mobility**
  - localization accuracy
  - location dependent services
  - location transparency
  - quality of service support (delay, jitter, security)
  - ...
- **Portability**
  - power consumption
  - limited computing power, sizes of display, ...
  - Usability

## Simple reference model used here (OSI-Layer Model)

- OSI: "Open System Interconnection Reference Model" („Offenes System für Kommunikationsverbindungen,")
- Layer Model of the Internationalen Standards Organisation (ISO)
- 1st Version of OSI Model released in 1983



## Mobile communication OSI-layer model



## Breitbandkommunikation – Einführung (PHY-Modell)

