UNIVERSITÄT OSNABRÜCK

Introduction to Mobile Communication

Mobile Communication, WS 2014/2015, Kap.1

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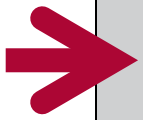
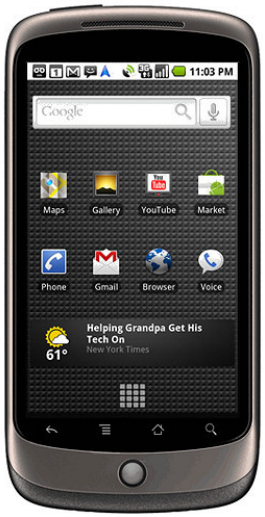


1. Introduction
2. Wireless Communication Basics
3. Wireless Medium Access Technologies
    1. Wireless LAN
    2. Bluetooth
    3. Performance Evaluation
    4. ZigBee & RFID
4. Cellular networks
5. Bricks for future Mobile Networking

1. Introduction

- Largest SW/HW/networked system
- Largest number of subscribers
- Mobile devices dominate the Internet
- Mobile applications dominate Internet usage
- New possibilities, new threats
- Technology fully integrated into everybody's life almost 24/7, almost anywhere



Computers for the next decades?

- Computers are integrated (>95% embedded systems!)
  - 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, message 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: NFC, piconets, wireless LANs, wireless WANs, regional wireless telecommunication networks etc.

1.2. Mobility versus portability

- Two aspects of mobility:
  - user mobility: users communicate (wireless) “anytime, anywhere, with anyone”
    - “**seamless services**”
  - 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
✓	✓	Smartphone

- What does it mean for the **client/server paradigm**?
  - **pure portability** is no big challenge
  - point of network attachment and the client IP address are irrelevant for the server
  - **seamless services** is a challenge
  - **reachability** of the mobile device
  - continuation of data connections of higher layers (TCP, applications, …) when **changing network attachment**

1.3. Wireless networks in comparison to fixed networks

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- 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
- Lower transmission rates
  - local some Mbit/s,
  - regional sometimes only, e.g., 53kbit/s with GSM/GPRS or about 150 kbit/s using EDGE
  - some Mbit/s with LTE
- Higher delays, higher jitter
  - connection setup time with GSM in the second range,
  - several hundred milliseconds for other wireless systems
  - in ms range with LTE
- 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

How mobile communication affects the layers

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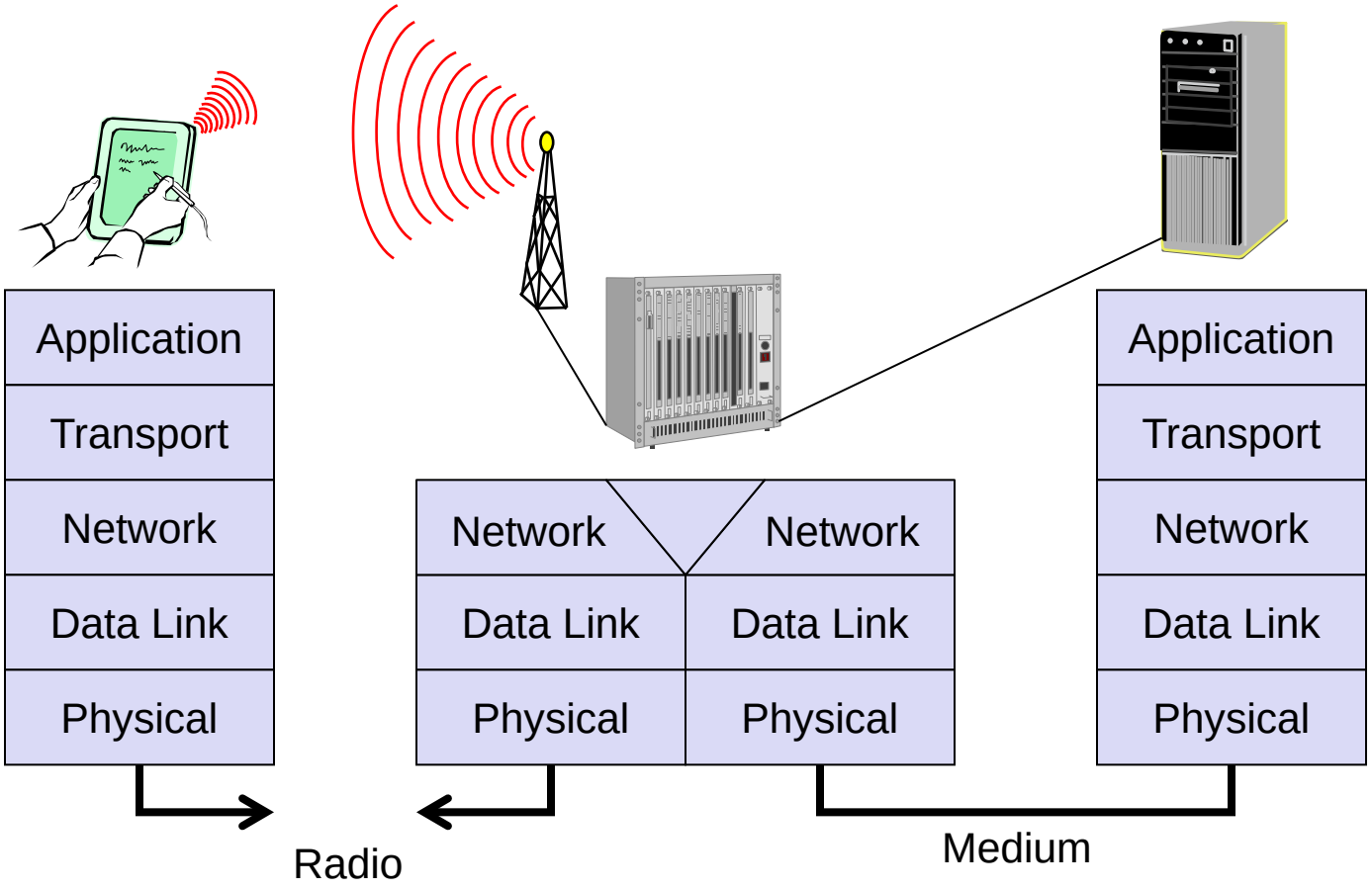
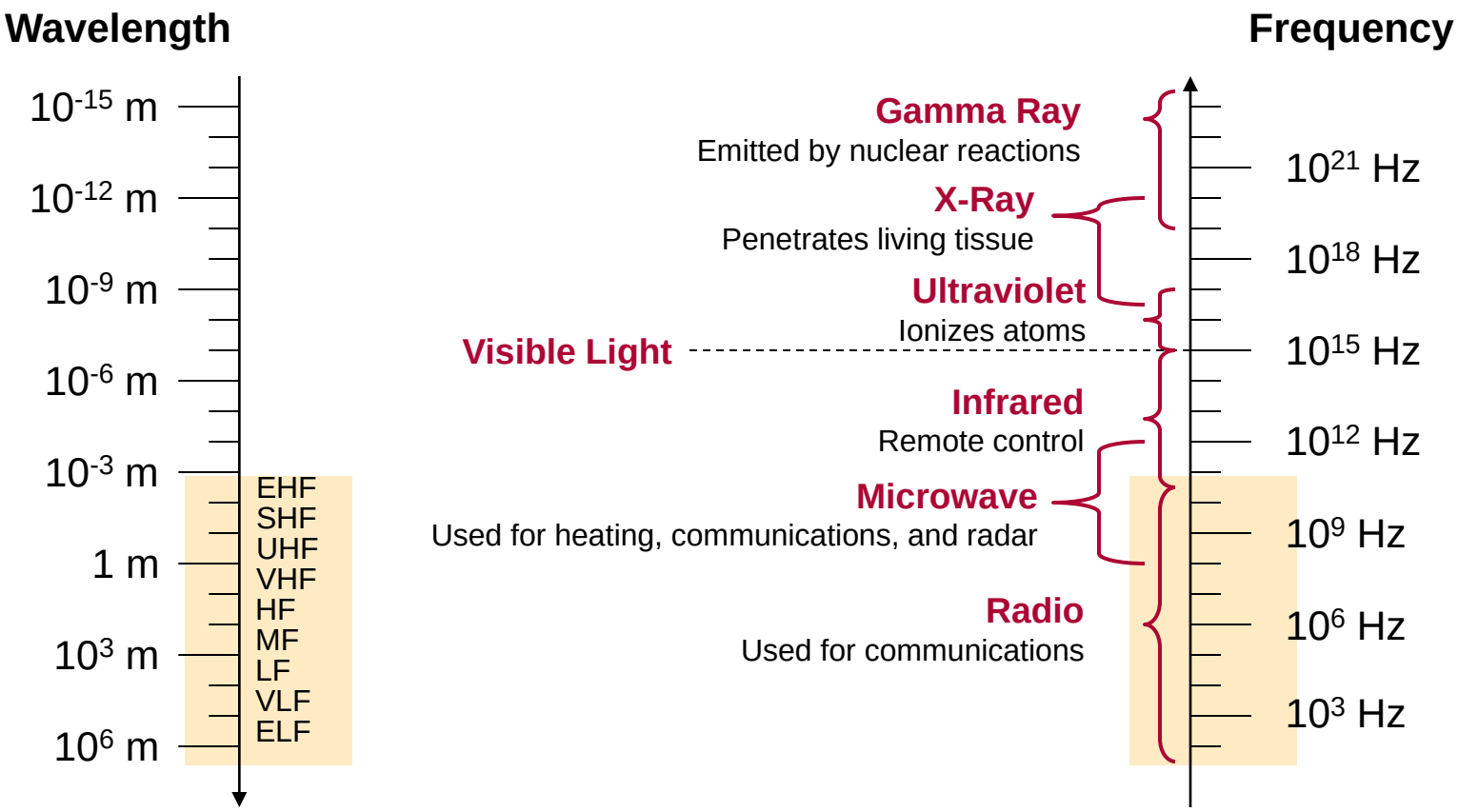
Application layer	• service location • new applications, multimedia • adaptive applications
Transport layer	• congestion and flow control • quality of service
Network layer	• addressing, routing, • device location • hand-over
Data link layer	• authentication • media access • multiplexing • media access control
Physical layer	• encryption • modulation • interference • attenuation • frequency

Wireless mobile communication obviously affects the **„last hop“.**
However, **tuning**, **changes** and/or **re-design** are also required in other places.



1.4. The electromagnetic spectrum



Reminder: $\lambda = c/f$ where λ = wave length, $c \cong 3 \times 10^8$ m/s = speed of light, f = frequency

Radio wavebands

Wavelength	Frequency	Common Name	Main Purposes
Above 100 km	Below 3 kHz	Extremely Low Frequency (ELF)	Submarine communications
10 -100 km	3 – 30 kHz	Very Low Frequency (VLF)	Maritime communications
1 -10 km	20 – 300 kHz	Low Frequency (LF) or Long Wave (LW)	AM broadcasting
100 -1000 m	300 -3000 kHz	Medium Frequency (MF) or Medium Wave (MW)	AM broadcasting
10 -100 m	3 – 30 MHz	High Frequency (HF) or Short Wave (SW)	AM broadcasting, amateur radio
1 -10 m	30 -300 MHz	Very High Frequency (VHF)	FM broadcasting, TV
0,1 -1 m	300 – 3000 MHz	Ultra High Frequency (UHF)	TV, cell phones
10 -100 mm	3 -30 GHz	Super High Frequency (SHF)	Fixed wireless, satellites
1 -10 mm	30 – 300 GHz	Extra High Frequency (EHF)	Satellites, radar

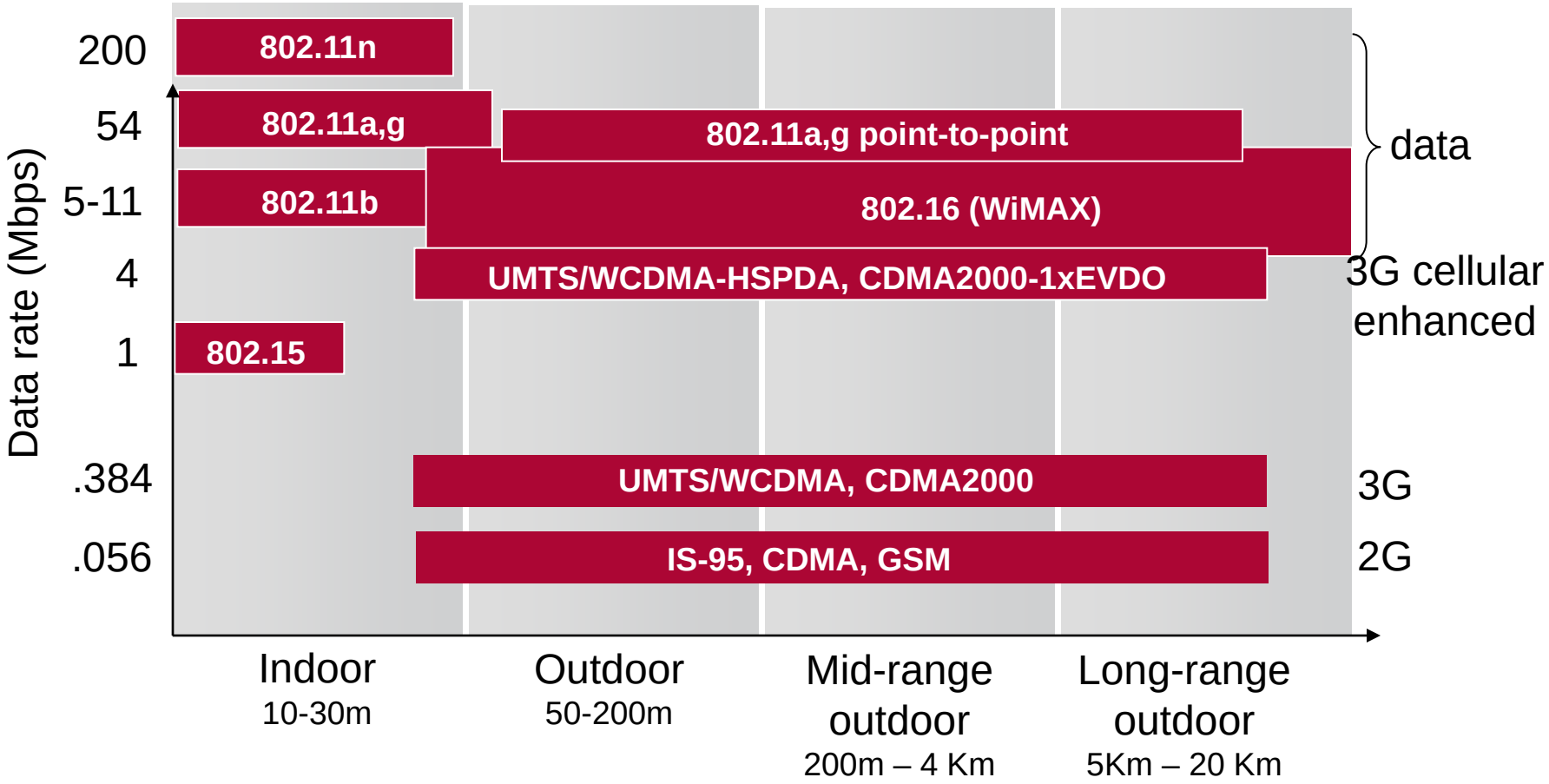
Source: Andy Dornan, „The Essential Guide to Wireless Communications Applications“, Prentice Hall, 2001, p. 19, 20

Microwave wavebands

Wavelength	Frequency	Band	Main Communications Use
193 – 769 mm	0.4 – 1.5 GHz	L	Broadcasting and cellular
57.7 – 193 mm	1.5 – 5.2 GHz	S	Cellular
48.4 – 76.9 mm	3.9 – 6.2 GHz	C	Satellites
27.5 – 57.7 mm	5.2 – 10.9 GHz	X	Fixed wireless, satellite
8.34 – 27.5 mm	10.9 – 36 GHz	K	Fixed wireless, satellite
6.52 – 8.34 mm	36 – 46 GHz	Q	Fixed wireless
5.36 – 6.52 mm	46 - 56 GHz	V	Future satellite
3.00 – 5.36 mm	56 - 100 GHz	W	Future cellular

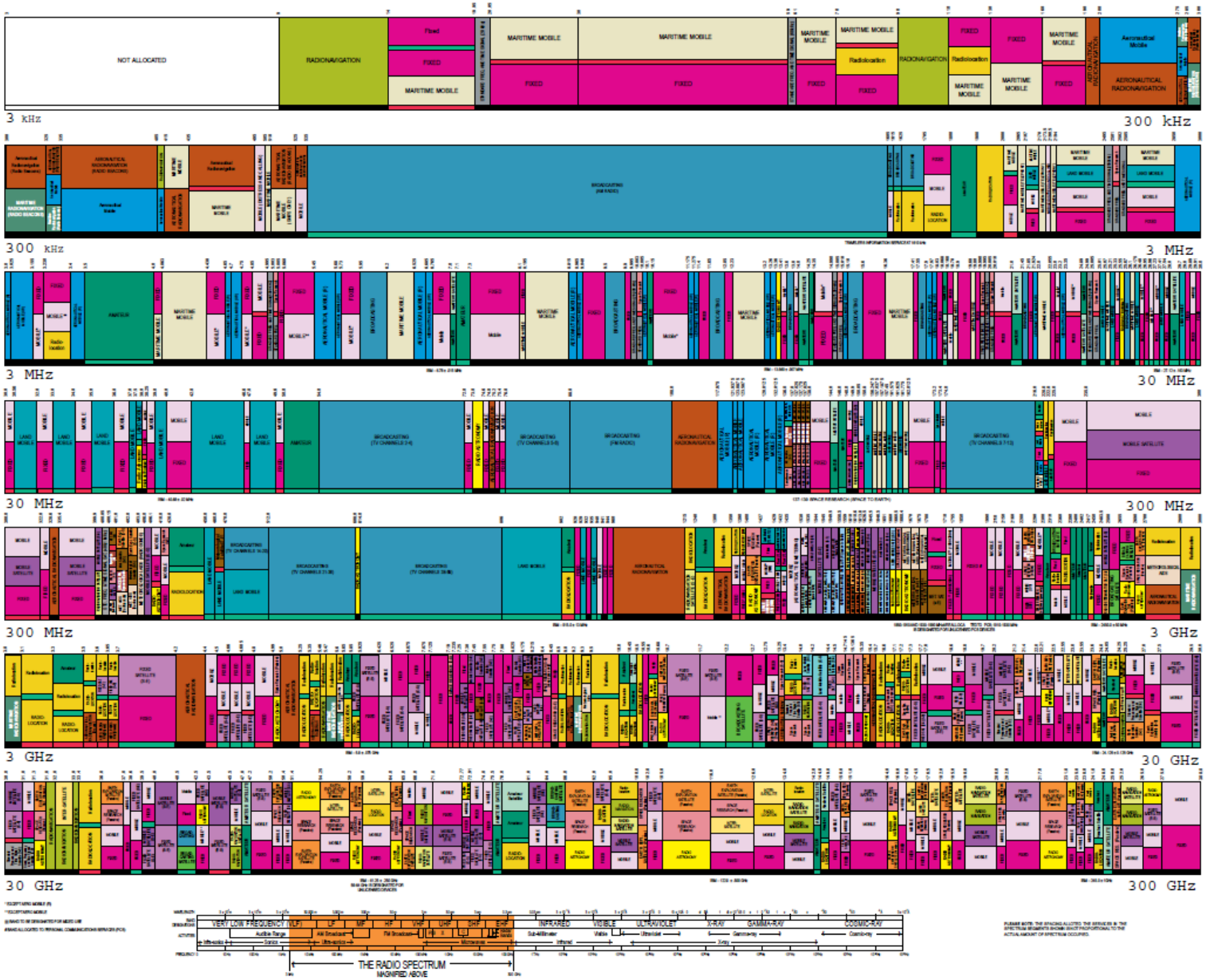
Source: Andy Dornan, „The Essential Guide to Wireless Communications Applications“, Prentice Hall, 2001, p. 20

Characteristics of selected wireless link standards



Source: Jim Kurose, Keith Ross: Computer Networking: A Top Down Approach - 5th edition, Addison-Wesley, April 2009.

Other Wireless Links – Spectrum Map – US



www.fas.org/spp/military/program/sigint/allochrt.pdf

Frequencies and regulations

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- In general: ITU-R holds auctions for new frequencies, manages frequency bands worldwide (WRC, World Radio Conferences)
- 3GPP specific: see e.g. 3GPP TS 36.101 V11.4.0 (2013-03)

Examples	Europe	USA	Japan
Cellular networks	**GSM** 880-915, 925-960, 1710-1785, 1805-1880 **UMTS** 1920-1980, 2110-2170 **LTE** 791-821, 832-862, 2500-2690	**AMPS, TDMA, CDMA, GSM** 824-849, 869-894 **TDMA, CDMA, GSM, UMTS** 1850-1910, 1930-1990	**PDC, FOMA** 810-888, 893-958 **PDC** 1429-1453, 1477-1501 **FOMA** 1920-1980, 2110-2170
Cordless phones	**CT1+** 885-887, 930-932 **CT2** 864-868 **DECT** 1880-1900	**PACS** 1850-1910, 1930-1990 **PACS-UB** 1910-1930	**PHS** 1895-1918 **JCT** 245-380
Wireless LANs	**802.11b/g** 2412-2472	**802.11b/g** 2412-2462	**802.11b** 2412-2484 **802.11g** 2412-2472
Other RF systems	27, 128, 418, 433, 868	315, 915	426, 868

One Solution: Cognitive Radio

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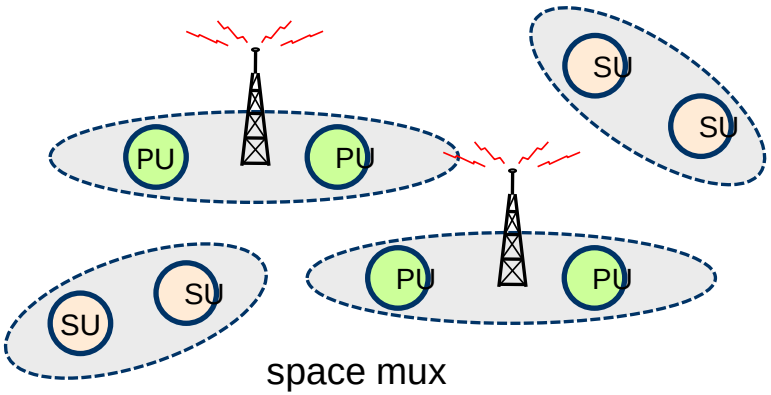
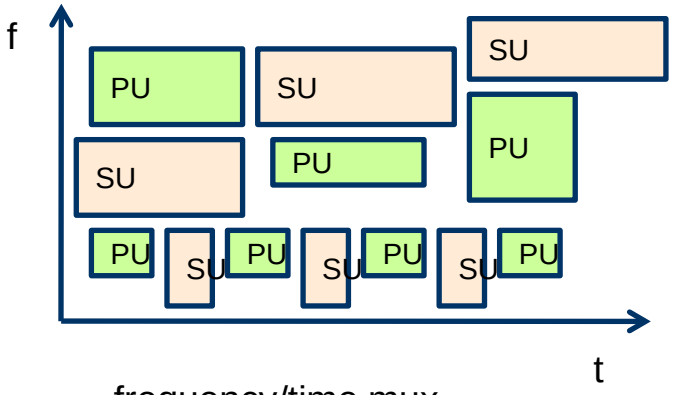
- Typically in the form of a spectrum sensing CR
  - Detect **unused spectrum** and share with others avoiding interference
  - Choose automatically **best available spectrum**
    - (intelligent form of time/frequency/space multiplexing)
- Distinguish
  - Primary Users (PU): users assigned to a specific spectrum by e.g. regulation
  - Secondary Users (SU): users with a CR to use unused spectrum
- Examples
  - Reuse of (regionally) unused analog TV spectrum (aka white space)
  - Temporary reuse of unused spectrum e.g. of pagers, amateur radio etc.

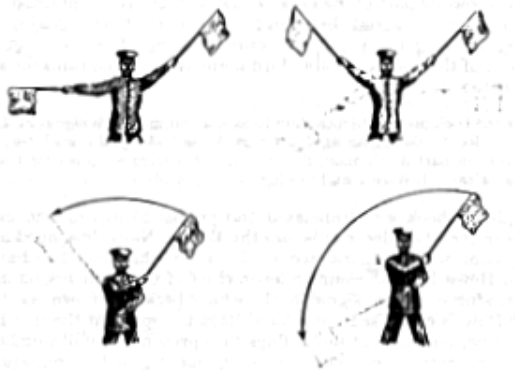


space mux



frequency/time mux

- **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)

Heinrich Hertz
1889 – 1894 Professor University of Bonn
Chair of Physics (Physikalisches Institut)

Mobile Communication in 1853

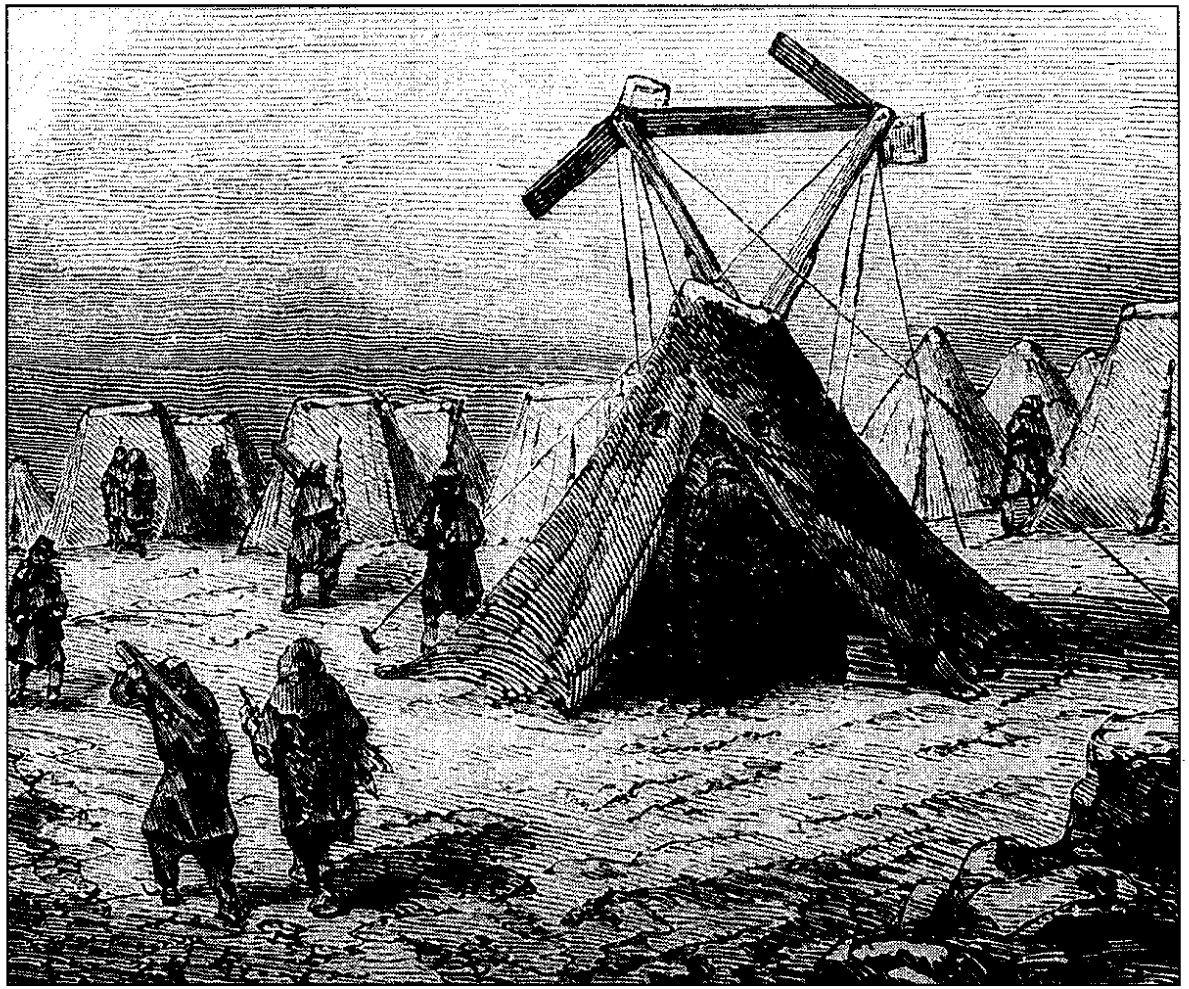
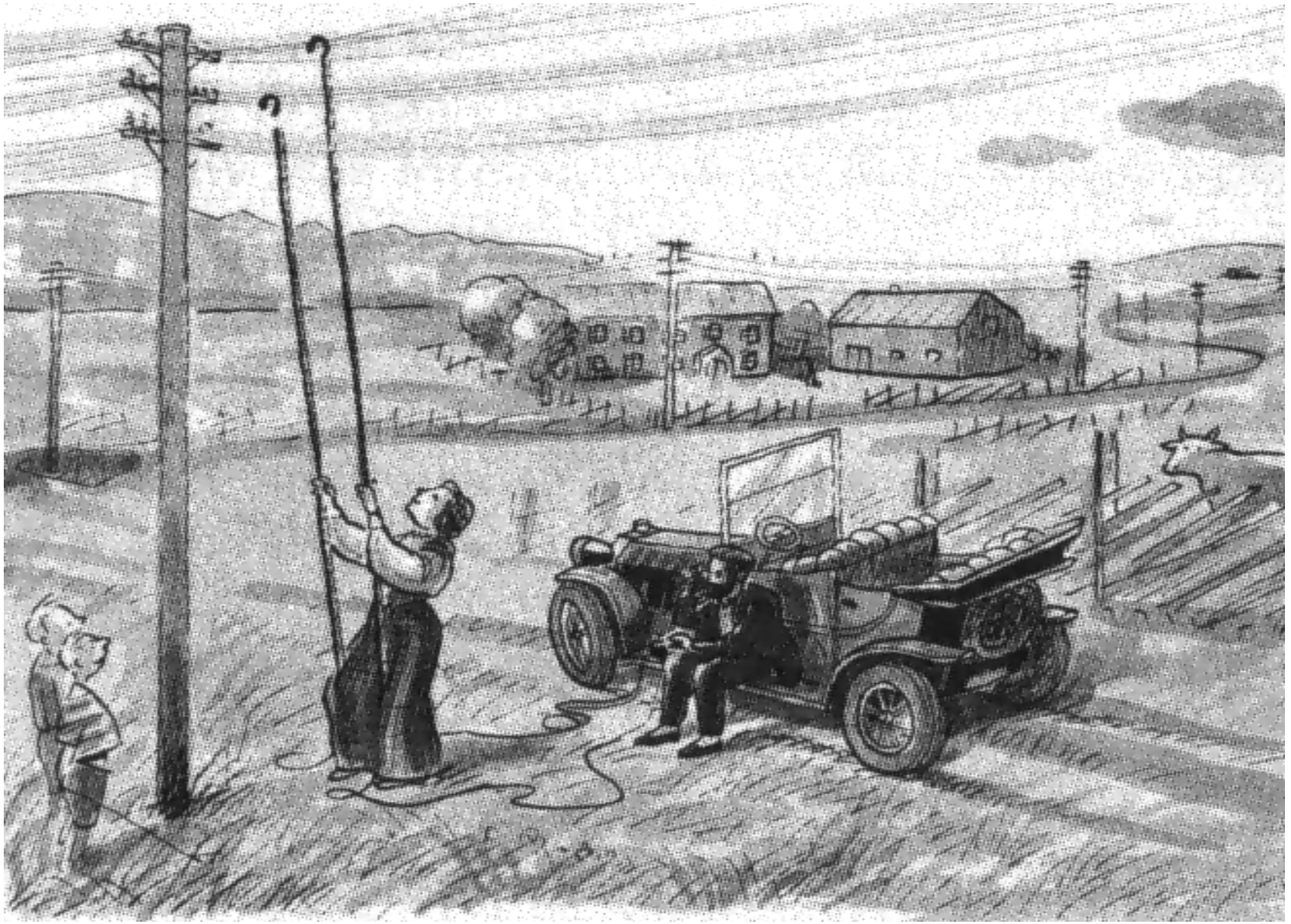


Figure 2.13 Mobile Semaphore Telegraph Used in the Crimean War 1853–1856.
(Source: [Belloc 1888])

Source:
G.J. Holzmann, B. Pehrson,
"The Early History of Data Networks",
IEEE 1995, ISBN 0-8186-6782-6

Mobile telephony in 1910



Source: Ericsson Connexion December 1994

- **1895 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

- **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**

- **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 170 countries
  - services: data with 9.6kbit/s, FAX, voice, ...

- **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

- **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 communication 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!)

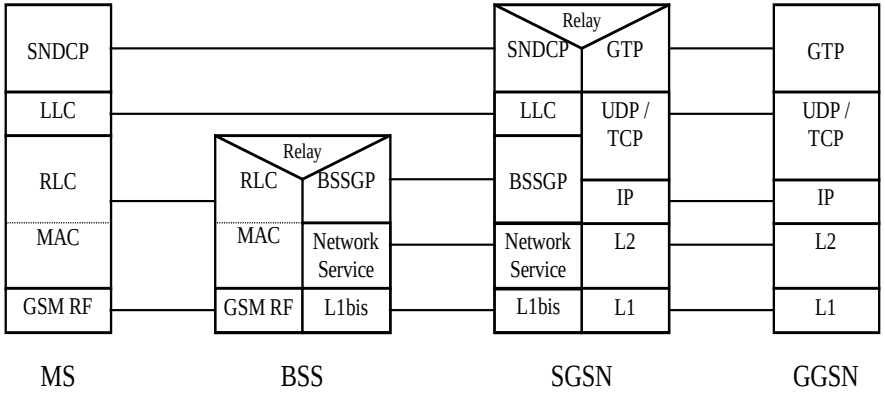
  UMTS auctions/beauty contests
  - **Hype** followed by **disillusionment**
    (approx. 50 B$ paid in Germany for 6 UMTS licences!)
- **2001 Start of 3G systems**
  - **Cdma2000** in Korea, **UMTS** in Europe, **Foma** (almost UMTS) in Japan

History of wireless communication (6)

- **2002** **WLAN hot-spots** start to spread
- **2003** - **UMTS** starts in Germany
  - Start of **DVB-T** in Germany replacing analog TV
- **2005** - **WiMax** starts as DSL alternative (not mobile)
  - first **ZigBee** products
- **2006** - **HSDPA** starts in Germany as fast UMTS download version offering > 3 Mbit/s
  - **WLAN** draft for 250 Mbit/s (**802.11n**) using MIMO
  - **WPA2** mandatory for Wi-Fi WLAN devices
- **2007** **over 3.3 billion subscribers** for mobile phones (NOT 3 bn people!)
- **2008** **"real" Internet** widely available on mobile phones (standard browsers, decent data rates)
  - 7.2 Mbit/s **HSDPA**, 1.4 Mbit/s **HSUPA** available in Germany,
  - more than 100 operators support **HSPA worldwide**,
  - first **LTE** tests (>100 Mbit/s)
- **2009** the story continues with **netbooks**, **iphones**, **VoIPoWLAN**…

Telecommunication

GSM -> GPRS -> UMTS -> HSPA -> LTE



Wireless Networks

WPAN -> WLAN -> WMAN