1. Introduction

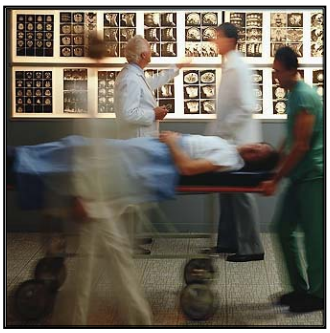
1.1. Everything moves …

Mobility is one of the watchwords of our society:

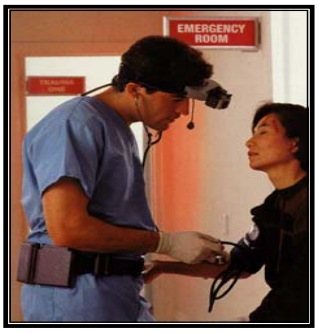
Everything moves. Faster and more frequently.

Wearable Applications (as discussed in IEEE 802 in March 1998)

Paint Inspection and Assembly Operation



Patient Monitoring using Sensors attached to the Patient



Assistance for medical and paramedical Personnel

Pilot Assistance

Automated Trading at the Stock Exchange

Enhancing the Guest Experience

Source: S. Case, „A Brief Survey of Wearable Applications“, doc.: IEEE 802.11-98/96, http://grouper.ieee.org/groups/802/15/pub/Tutorials.html

Wearable Applications (as discussed in IEEE 802 in March 1998)

War of the Cyborgs ?

Source: D. Braley, „Wearables Standards“, doc.: IEEE 802.11-98/96, http://grouper.ieee.org/groups/802/15/pub/Tutorials.html

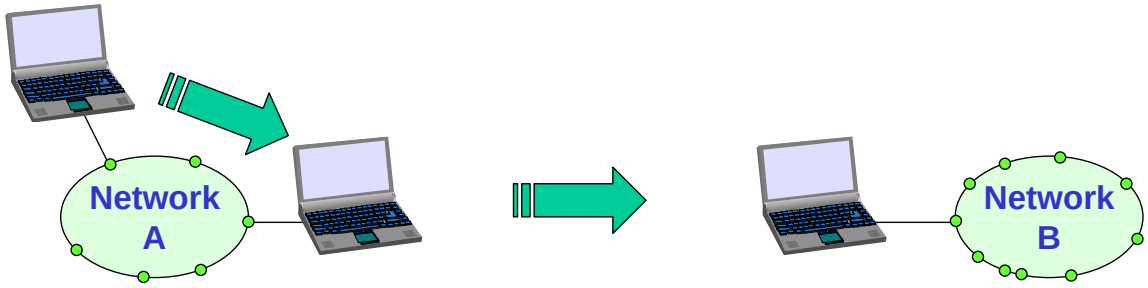
1.2. Mobility versus portability

Today, a lot of computer applications require network access.

Portable operation of a computer:

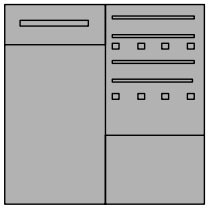
The computer
- can be operated **at any of a set of points of attachment**,
- usually **cannot be operated while being moved.**

⇨ **Network connections** are
- **shut down** and
- **re-initialized** at the new point of attachment



The client/server paradigm

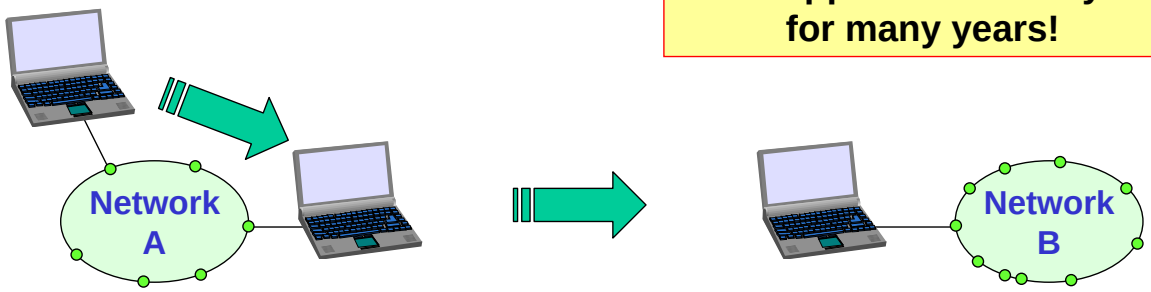
The **mobile device is the client** and uses client applications such as:



Central servers in the Internet

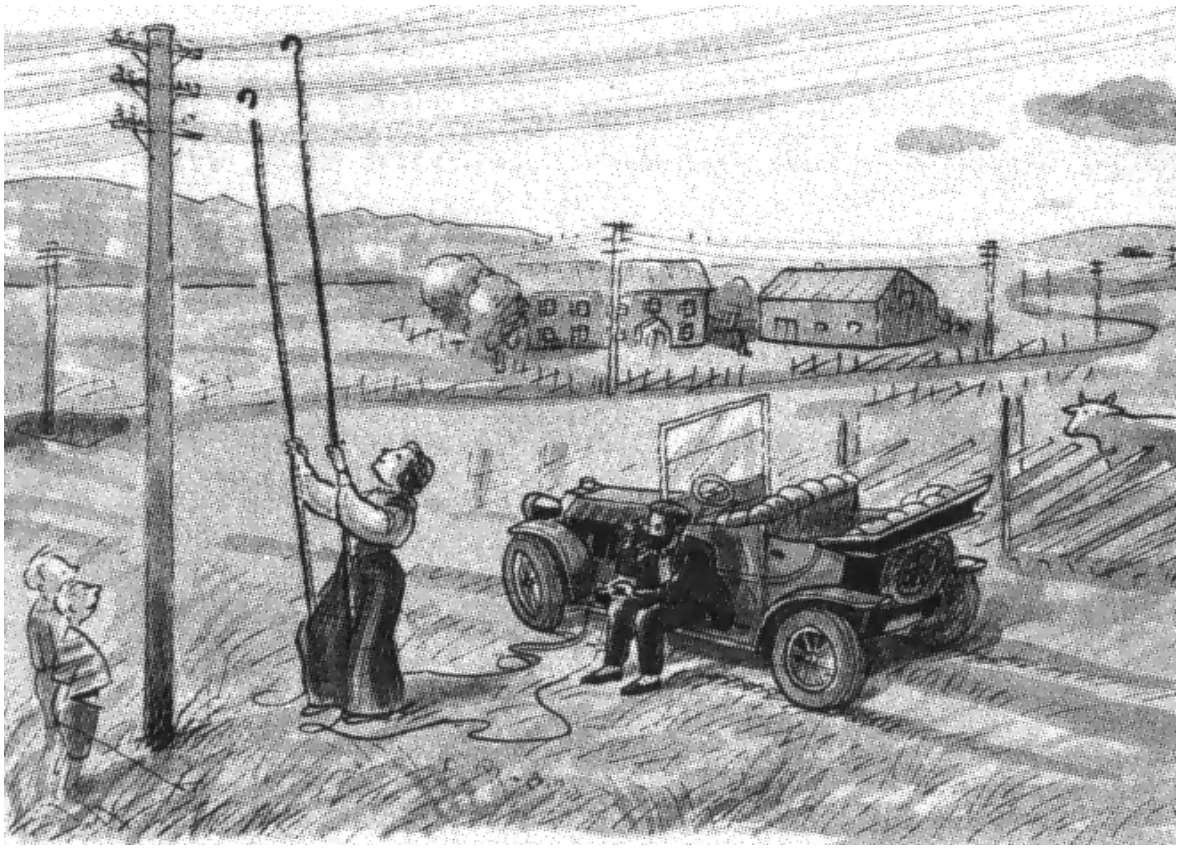
- E-Mail: access to centralised E-Mail servers via POP, IMAP, WWW
- browsing the WWW, download documents and files
- remote login (telnet, ssh)
- remote file transfer (ftp, scp)
- …

This is no challenge with the portability principle as applicable already for many years!



The point of network attachment and the client IP address are irrelevant for the server!

Mobile telephony in 1910



Source: Ericsson Connexion December 1994

Truly mobile operation

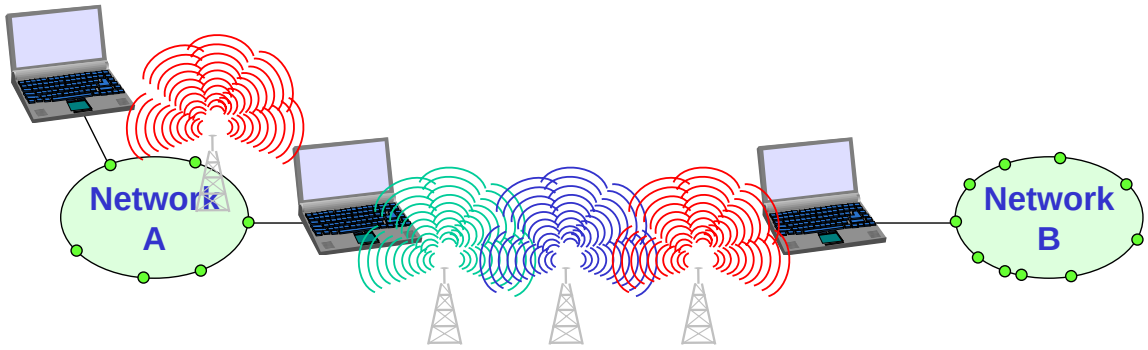
Truly mobile operation of a computer:

The computer

- can (at least almost) **continuously remain in contact** with the network resources required by the applications.

➡ **Neither the system nor the applications** running on the system need to be **re-initialized or restarted, ...**

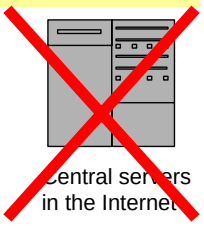
➡ **... even if the network connectivity is frequently broken and re-established at new points of attachment.**



A paradigm shift

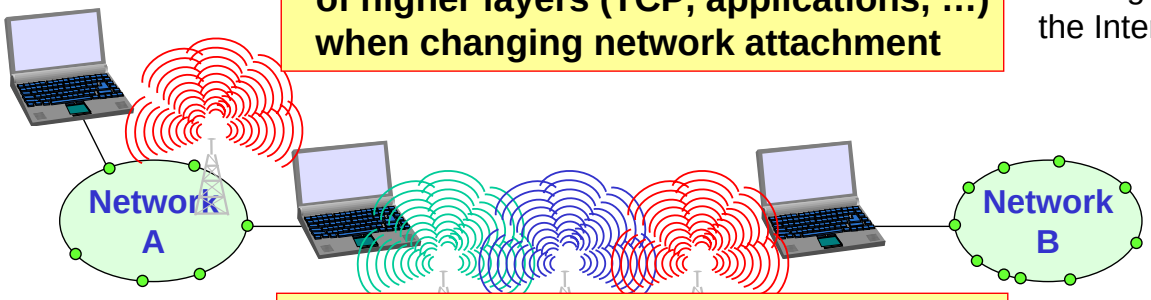
The **mobile device becomes a server** and offers services to any other (mobile or fixed) device in the Internet:

- resource sharing, peer to peer
- direct reachability, e.g. VoIP without server(s)
- …



Mobile server, moving within the Internet!

Important challenges of truly mobile operation:
- **reachability of the mobile device**
- **continuation of data connections of higher layers (TCP, applications, …) when changing network attachment**



A change of the IP address of the mobile device must be hidden for protocol layers above IP!

1.3. Mobile devices *JS*

Pager
- **receive only**
- tiny displays
- simple text messages

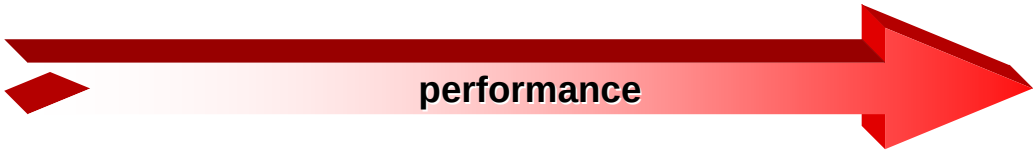
Sensors, embedded controllers

Mobile phones
- **voice, data**
- simple graphical displays

PDA
- simple graphical displays
- character recognition
- **simplified WWW**

Palmtop
- tiny keyboard
- **simple versions of standard applications**

Laptop
- fully functional **standard applications**



Effects of device portability

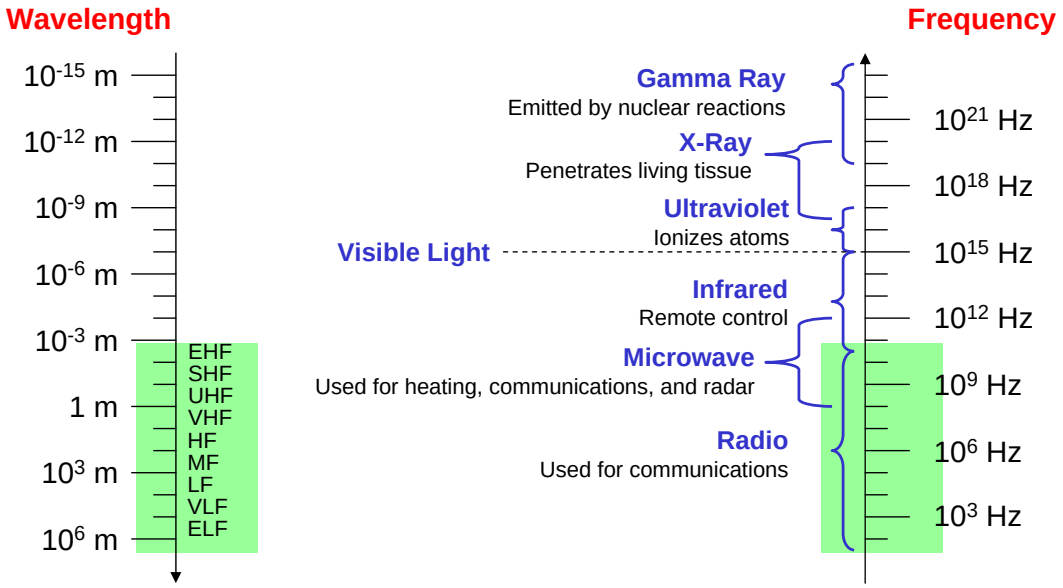
JS

- **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

1.4. Wireless communication

Obviously, user mobility is very limited in the wired world …

1.4.1. 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

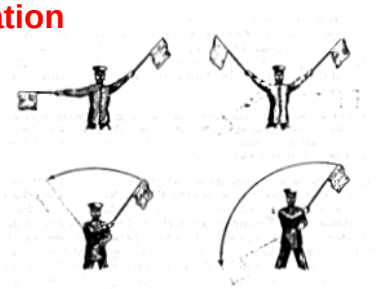
Microwave wavebands

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

1.4.2. Early history of wireless communication *JS*

- **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)

1.4.3. History of wireless communication JS

- **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

History of wireless communication (2) JS

- **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 (3) JS

- **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, ...

History of wireless communication (4) JS

- **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 (5) JS

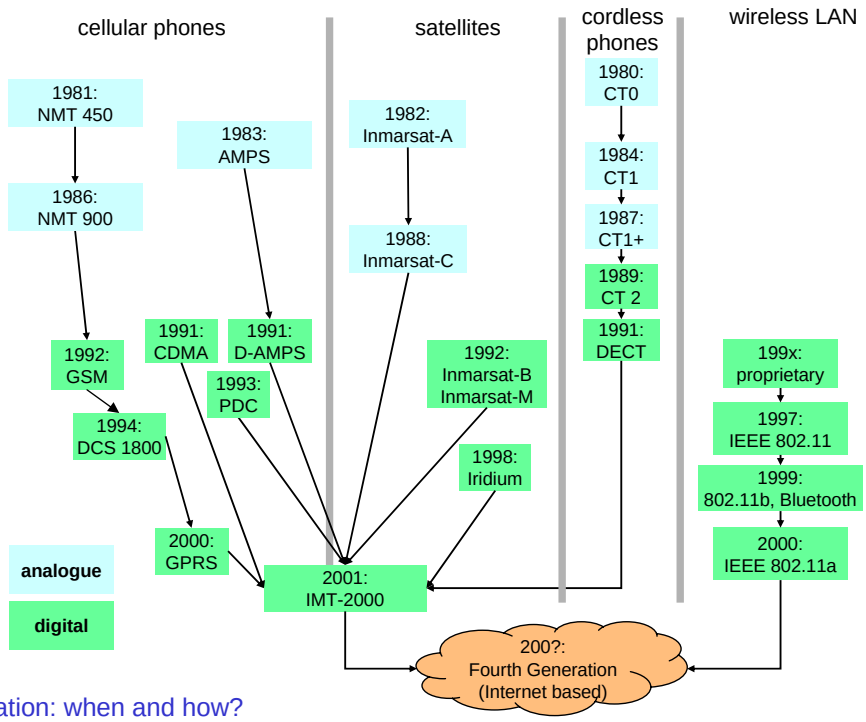
- **1999 Standardization of additional wireless LANs**
  - **IEEE standard 802.11b**, 2.4-2.5GHz, 11Mbit/s
  - **Bluetooth** for piconets, 2.4Ghz, <1Mbit/s

  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

1.4.4. Wireless systems: Overview of the development JS



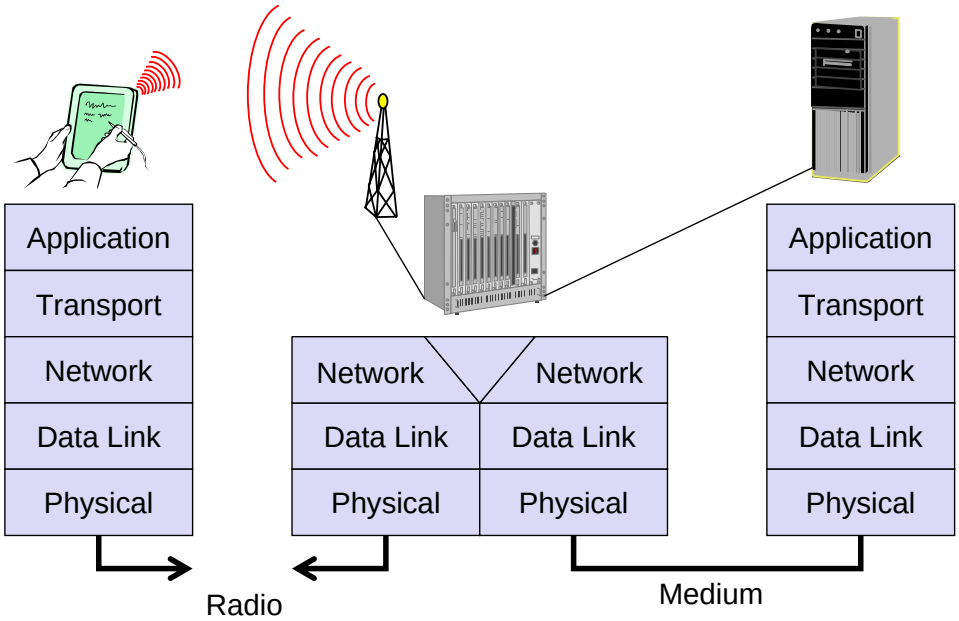
4G – fourth generation: when and how?

1.4.5. Wireless networks in comparison to fixed networks JS

- **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., **9.6kbit/s with GSM**
- **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**

1.5. Mobile communication and the layer model JS

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



How mobile communication affects the layers

JS

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