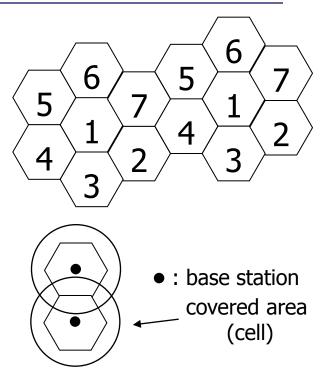# Communication Networks 2

Mobile networks

Gusztáv Adamis

BME TMIT

2016

Earth surface mobile networks

- Cellular concept:
    - frequency range is divided into several (e.g. 7) parts
    - cellular coverage (see picture)
    - same frequency: distance of 2 cells – no interference
    - this is only theoretical – in practice more complicated situations (base station in the „corner" of the cell, cell divided into several sectors, etc.)
- Size of a cell?
- Advantages of small cells:
    - small transmitter power enough
        - minimisation of physiological risk
        - smaller power consumption
    - higher traffic density
- Disadvantages of small cells :
    - lot of base stations needed
        - more expensive
        - nasty

● : base station

covered area (cell)

1G systems

- 1G: first generation mobile telecommunication systems
  - end of 1970s / beginning of 1980s
  - Analogue systems
  - Lot of not compatible systems
  - E.g.: NMT (Nordic Mobile Telephone System)
    - Scandinavia since 1981
    - In Hungary 1990-2003. (30th June) (Westel 0660)
    - Typically around 450 MHz frequency
    - Relatively large cells, with 30-50 km of diameter
    - Poor voice transmission quality, few services
  - More examples for 1G systems:
    - USA: Advanced Mobile Phone Service (AMPS),
    - GB: Total Access Communication System (TACS)
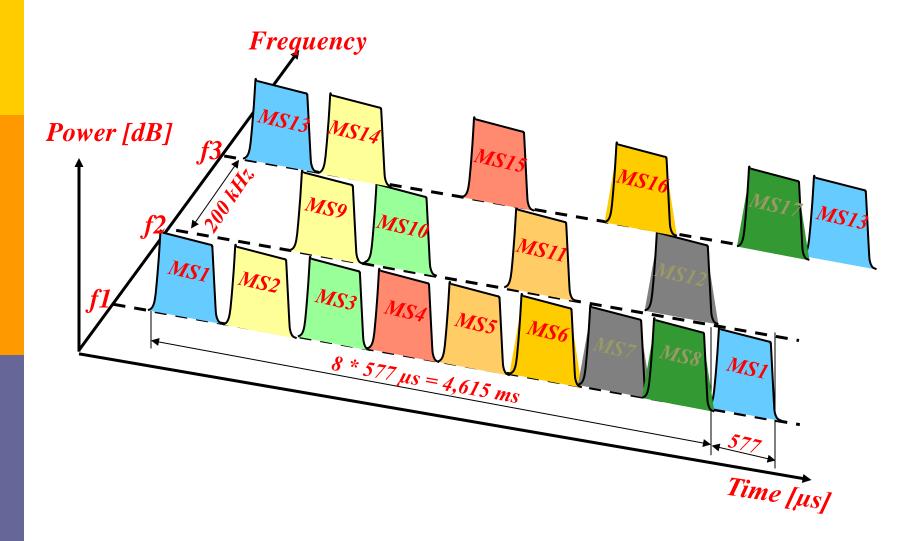   - Germany: B-Network (C450)

GSM

- World-wide spread, because:
  - research-development in proper time, quickly (4 years)
  - open, improvable standard (ETSI)
    - in Europe uniform from the beginning (not in USA ☹)
  - global system (roaming)
  - concept of SIM card is attractive (data of subscribers – equipment-independent)
  - only the caller pays (in USA both parties)
  - pre-paid (later from phase 2)
  - 900 MHz: countrywide coverage possible
- Incremental development:
  - phase 1 (1991)
    - voice transmission, SIM concept, SMS, roaming, encryption of voice, 9.6 kbps data transmission
  - phase 2 (1995)
    - backward compatibility, calling number presentation, call hold, call waiting, conference call, half rate (speed) codec, etc.
  - phase 2+ (1998)
    - mainly improvement in data transmission (HSCSD, EDGE, GPRS), push-to-talk, virtual private networks, improvement of SIM, enhanced codecs, etc.
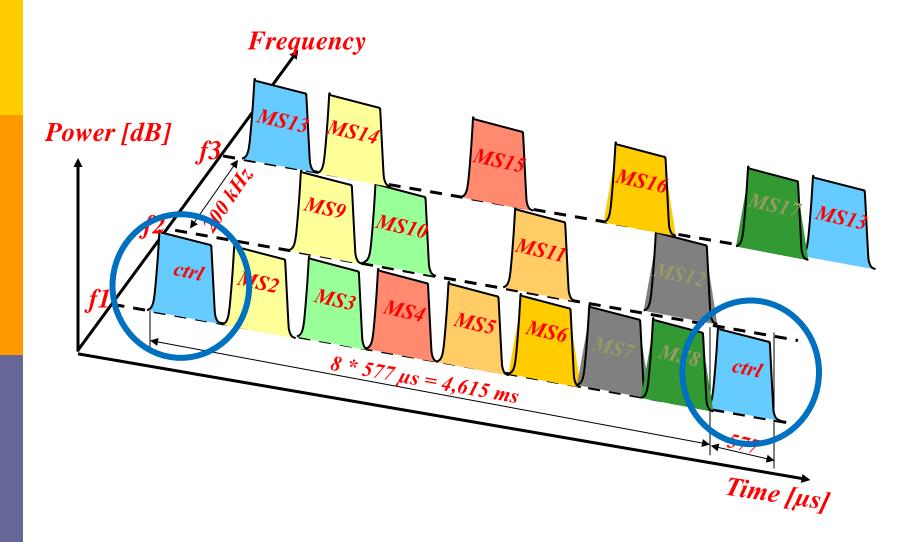
GSM

- ❑ Digital transmission:
  - ▪ voice codec in terminal
  - ▪ integrated services network: voice + data transmission
- ❑ Radiation output: max. 2W, adaptive: the terminal transmits with the minimally necessary power
  - ▪ save the battery
  - ▪ minimisation of physiological risk
  - ▪ not to disturb other cells
- ❑ Diameter of cells: 0,5 – 35 km
  - ▪ depends on frequency, traffic, propagation
  - ▪ design decision

GSM

- Radio access: FDMA+TDMA (Frequency/Time Division Multiple Access)
- GSM 900 (Primary-GSM, P-GSM)
  - mobile station (uplink): 890-915 MHz,
  - base station (downlink) 935-960 MHz
  - in this frequency range the smaller frequency suffers smaller attenuation, so it requires less power -> mobiles have the smaller frequency band
  - 1 band = 25 MHz, 1 carrier = 200 kHz: 124 carriers (FDMA)
    - shared by every service provider
    - in Hungary: appr. 30 frequencies/service provider in this band
  - 8 time slots/carrier (TDMA)
  - 30*8/10 $\approx$ 24 channels / cell
    - 10: typically $\approx$ 10 different frequencies used in cells (more realistic than 7 as we could see on slide 4)
    - with Half Rate encoding: twice as much
  - max 35 km cell diameter: 900 MHz waves follow the surface of the Earth more or less =>
    - countrywide coverage
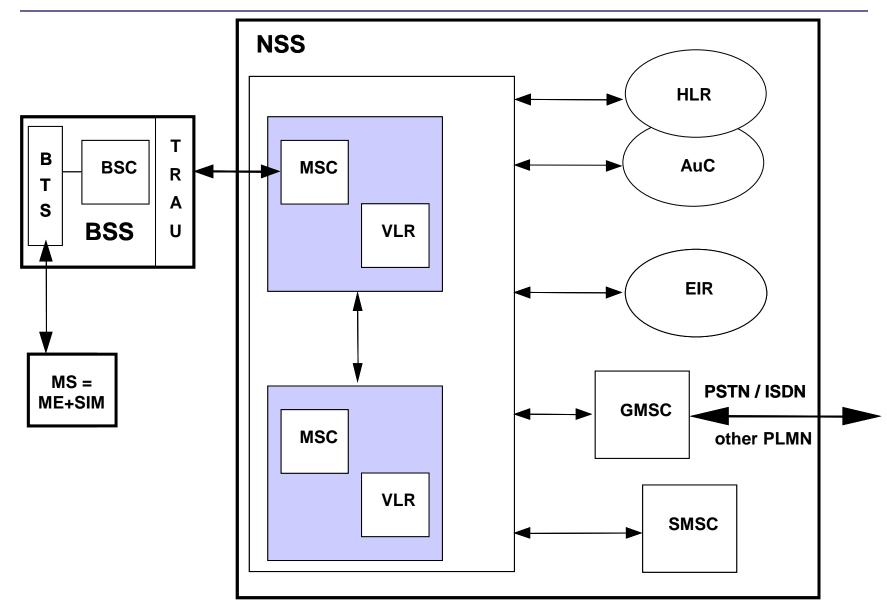
FDMA – TDMA access

FDMA – TDMA access

GSM

- GSM 1800
  - mobile: 1710-1785 MHz, base station: 1805-1880 MHz
  - 1 band = 75 MHz (three times larger capacity)
  - BUT: worse wave propagation
    - propagates straight
    - attenuates more quickly
  - not (so...) suitable for countrywide coverage, only for small cells (with high traffic)
- Several other: (not to learn, but interesting)
  - Extended-GSM 900, E-GSM: +10 MHz/direction: +50 carriers
  - R-GSM: Railways GSM: 876-880/921-925 MHz
  - GSM 1900: 1850-1910/1930-1990 MHz (USA)
  - GSM 850: 824-849/869-894 MHz (USA)
- Dual band equipments: automatically select/change frequency range
  - recently three band (900/1800/1900) and four band equipments (850/900/1800/1900)

GSM handover/handoff

- GSM: circuit switching
- When the mobile station enters an other cell: handover (handoff)
  - connection continuous
  - it can theoretically happen:
    - by control of the mobile station: measures, when the signal of the neighbouring cell is stronger
    - by control of the network: network decides on the signal strength and/or other pieces of info (e.g. load of the cell)
    - *by control of the network, with the help of mobile station: network asks the mobile station to send signal strength info, but the decision is made by the network* – this is in GSM
      - this way the network can enter the mobile station later if the „new" cell is overloaded

Architecture of GSM networks

Base Station Subsystem (BSS)

- ❑ Base Transciever Station (BTS)
  - ■ One or more elementary transmitter/receiver
  - ■ Transcoder/Rate Adapter Unit, TRAU
    - ❑ FR, HR, EFR codec ⇔ 64 kbps PCM
      - ▪ Full Rate (13 kbps), Half Rate (5.6 kbps), Enhanced Full Rate (12.2 kbps, but better than FR)
    - ❑ Rate adaptation also at data transmission: 14.4 kbps ⇔ 64 kbps

- ❑ Base Station Controller (BSC)
  - ■ Controls one or *more* BTSs
  - ■ Radio channel assignment
  - ■ Handover control

Network and Switching Subsystem

- Mobile Switching Centre (MSC)
  - a digital switch
  - with mobile specific extensions
    - authentication
    - location management (VLR)
    - inter-BSC handover
    - roaming
- Visitor Location Register (VLR)
  - Built-in the MSC
  - Stores temporarily some parts of the HLR info about the currently served mobile stations
- Home Location Register (HLR)
  - subscriber data, subscription information (services), current location
  - one HLR in every network
- Authentication Centre (AuC)
  - Typically integrated with HLR
  - It verifies that the subscriber is the same in reality as he is proposed to be

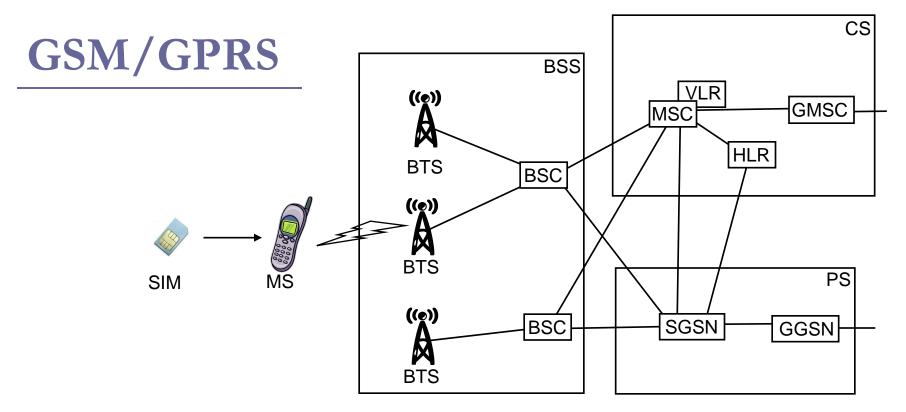# GSM services – 1

- ❑ Voice transmission
  - ■ speed of codec 13 kbps (later: 5.6 kbps)
  - ■ compromise: poorer quality of voice, but higher utilisation of frequency
- ❑ SMS (Short Message Service)
  - ■ max. 160 character (1 character = 7 bits)
- ❑ Data transmission
  - ■ originally 9.6 kbps, later 14.4 kbps
- ❑ HSCSD (High Speed Circuit Switched Data)
  - ■ enhancement of data transmission: unites more 14.4 kbps channels
  - ■ max. 8 theoretically
  - ■ max. 4 practically, (to fit into one 64 kbps channel
    - ❑ typical speed: 43.2, 57.6 kbps
  - ■ circuit switched, 4 channels simultaneously: EXPENSIVE!

GSM services – 2

- ## EMS (Enhanced Messaging Service)
  - simple pictures
- ## MMS (Multimedia Messaging Service)
  - multimedia message: picture, text, voice together
  - since 2002
- ## WAP (Wireless Application Protocol)
  - simplified Web-like service
- ## Location Based Services
  - relatively imprecise (cell level!),
  - but it can be told e.g., where is a restaurant nearby

GSM/GPRS

- GPRS (General Packet Radio Service)
  - since 2001
  - packet switched data transmission, extension of GSM
  - advantage:
    - better utilisation of network, frequency
    - payment on basis of transmitted data amount (kB), not on basis of duration of the connection
  - speed
    - originally max. 56 kbps
    - theoretically max.: 8 x 20 = 160 kbps
    - typically 60-80 kbps downlink, 20-40 kbps uplink
      - fewer channels used in uplink direction
  - usage:
    - WAP
    - Internet access
  - requires significant extensions in the network (next slide)

GSM/GPRS

SIM: Subscriber Identity Module,
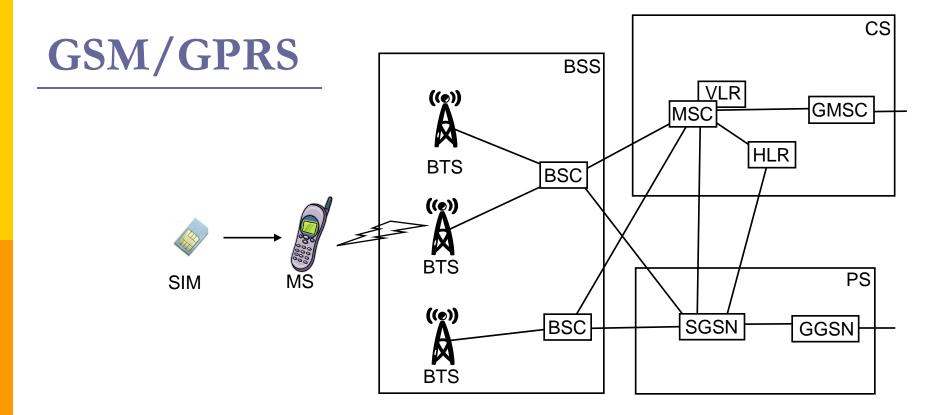
MS: Mobile Station

BTS: Base Transciever Station

BSC: Base Station Controller
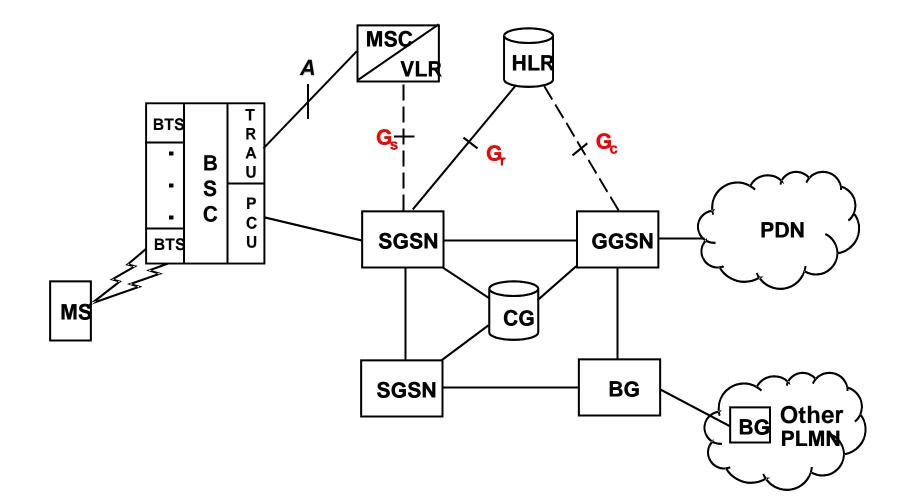
BSS: Base Station Subsystem

CS: Circuit Switched Subsystem
- MSC: Mobile Switching Centre
- VLR: Visitor Location Register
- HLR: Home Location Register
- GMSC: Gateway MSC
- + other units: AuC, EIR, SMSC

GSM/GPRS

PS: Packet Switched Subsystem

- ■ SGSN: Serving GPRS Support Node
- ■ GGSN: Gateway GPRS Support Node (to other data networks e.g. Internet)
- ■ BG: Border Gateway (gateway to other GPRS service providers)

GPRS architecture

GSM/EDGE

- *EDGE* (Enhanced Data Rate for Global/GSM Evolution – no comment...)
  - since 2003
  - can be used for speeding up the
    - circuit-switched data transmission: Enhanced Circuit Switched Data (ECSD)
    - packet-switched data transmission: Enhanced GPRS (EGPRS)
  - improved modulation technology
    - originally 1 bit/symbol (Gaussian minimum shift keying, GMSK)
    - EDGE: 8PSK, 3 bit/symbol
    - three times larger data transmission speed
    - but worse signal-to-noise ratio
    - can only be used close to the base station, not in the whole cell
  - requires only a limited extensions in the network: EDGE card into the base station + BSC software upgrade