Communication Networks 2

Mobile networks 2.

Gusztáv Adamis

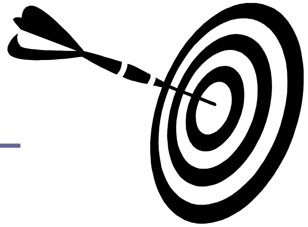
BME TMIT

2019

UMTS

- UMTS: Universal Mobile Telecommunication System
- ITU: IMT-2000 (International Mobile Telecommunications-2000) standard
  - UMTS (Eu)
  - FOMA: Freedom of Mobile Multimedia Access (Japan)
    - UMTS compatible
  - CDMA2000: Code Division Multiple Access (US)
- UMTS also has subversions ☹
- 3GPP: 3rd Generation Partnership Project standardises
    - www.3gpp.org

UMTS goals



- UMTS goals:
  - better quality of voice (same as in ISDN)
  - better utilisation of spectrum
  - higher data transmission speed
  - backward compatibility with GSM

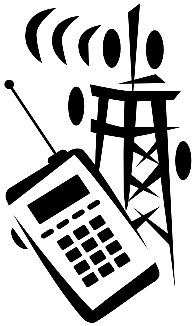
UMTS services

- Voice transmission:
  - Adaptive MultiRate (AMR) codec 4.7 – 12.2 kbps
- Data transmission, Internet access
  - in cities: typically max. 384 kbps, under 120 kmph
  - in rural areas: typically max. 144 kbps, 500 kmph
  - in buildings: max. 2 Mbps, under 10 kmph
- Value added services
  - chat, games, music download, etc.
  - location based services:
    - e.g. where is my girlfriend?, where am I ?!, ATM, pub;
    - emergency call, location based accounting (!)

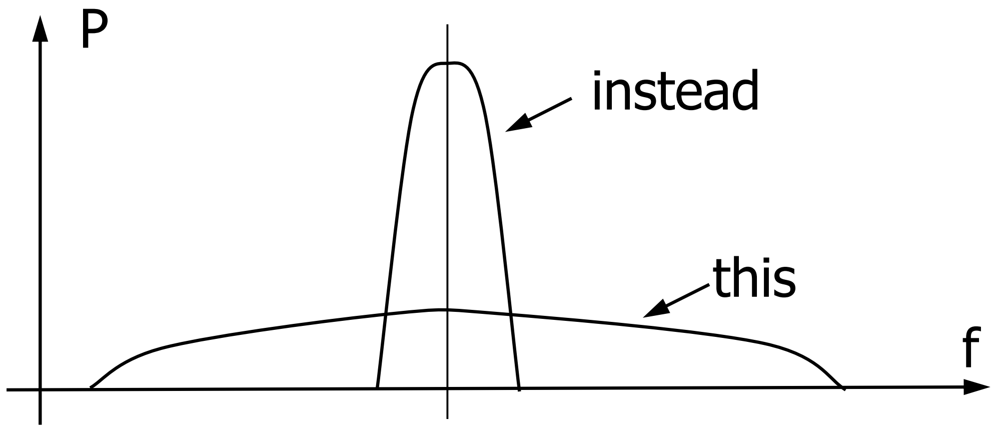
UMTS services

- Multimedia services
  - voice transmission
  - data transmission
  - video telephony
  - TV
  - Radio
  - Traffic monitoring cameras
  - Weather cameras
  - Downloading music, videos - streaming
  - Etc, etc.

Radio interface



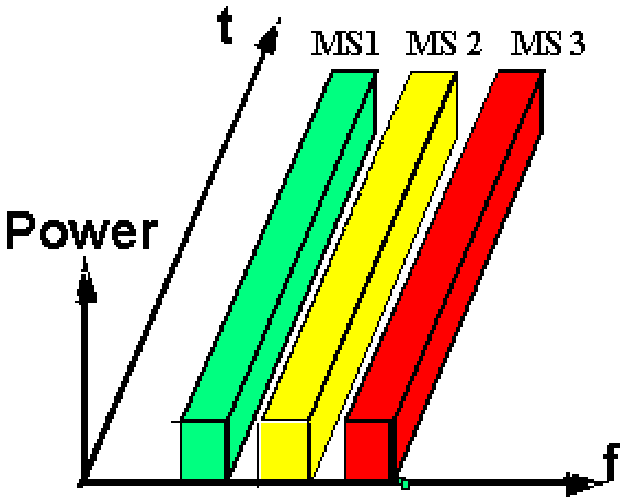
- Frequencies:
  - 1885-2025 MHz uplink
  - 2110-2200 MHz downlink
    - reserved for satellite: 1980-2010 MHz up, 2170-2200 MHz down
- Medium access:
  - *CDMA*, Code Division Multiple Access
  - Same frequency, same time, different code
    - like: multilanguage airport lobby
  - Every signal is spread in the whole spectrum, but with small power
  - Goal: better utilisation of the spectrum

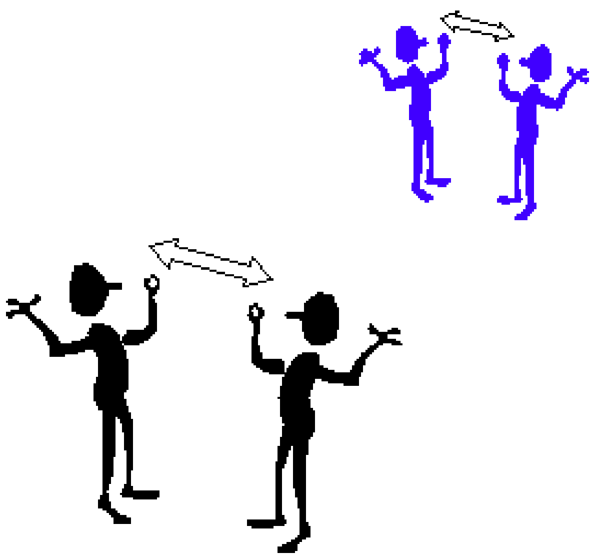


FDMA

Frequency Division Multiple Access

- Orthogonal in frequency within cell
- Narrow bandwidth per carrier
- Continuous transmission and reception
- No synchronization in time

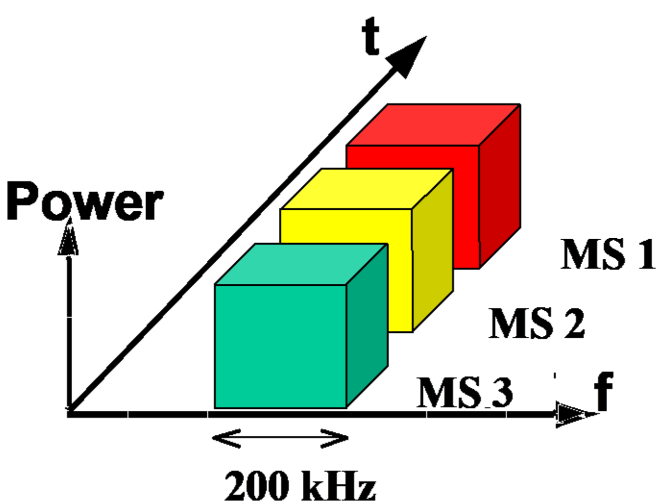




TDMA

Time Division Multiple Access

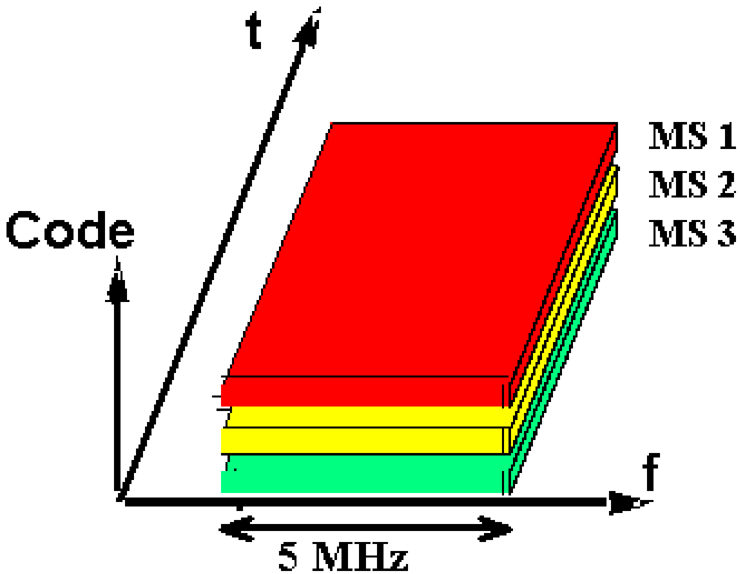
- Orthogonal in time within cell
- Increased bandwidth per carrier
- Discontinuous transmission and reception
- Synchronization in time



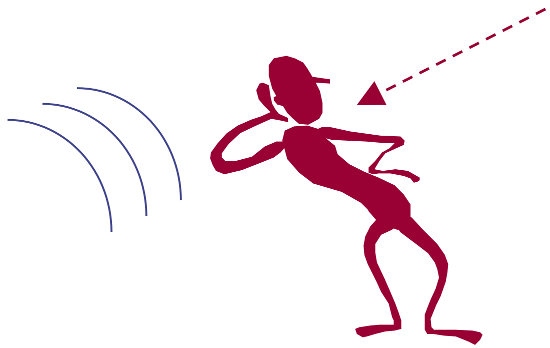
CDMA

Code Division Multiple Access

- Separate users through different codes
- Large bandwidth
- Continuous transmission and reception

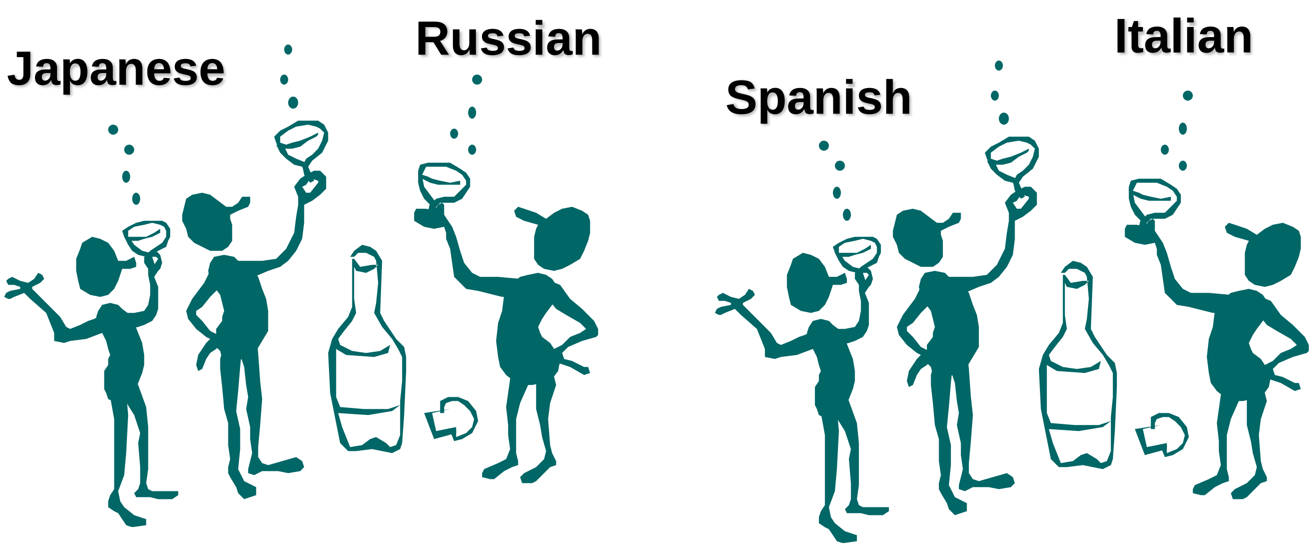


CDMA International Cocktail Party

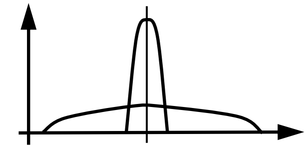


What can YOU hear/understand...

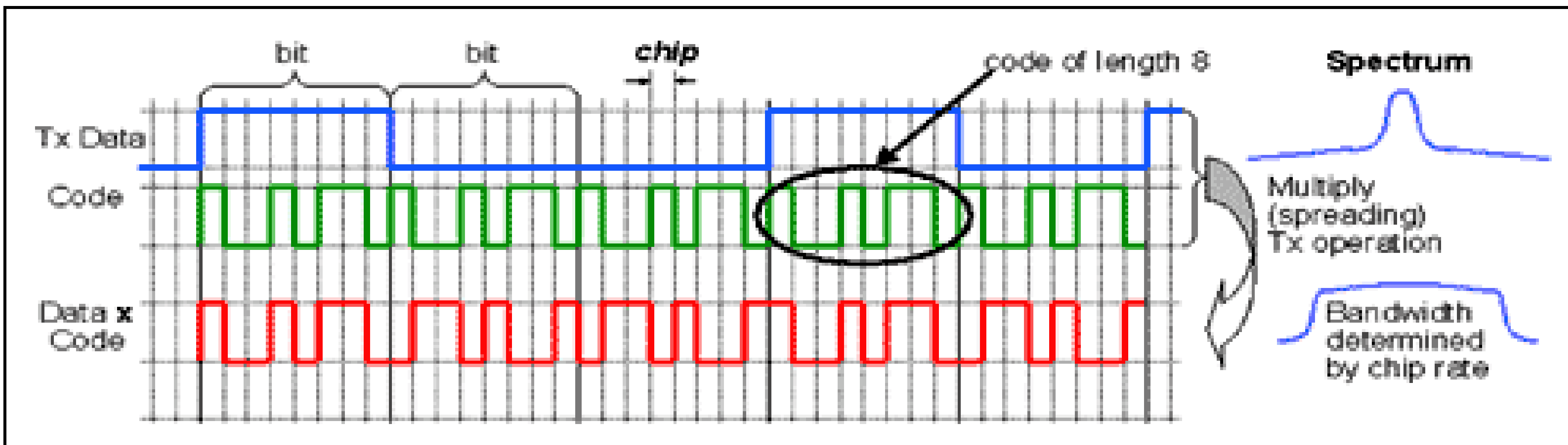
- ....if you speak only Japanese?
- ....if you speak only English?
- ....if you speak only Italian?
- ....if you speak only Japanese, but the Japanese-speaking man is at the other corner of the hall?
- .... if you speak only Japanese, but the Spanish cries loudly?



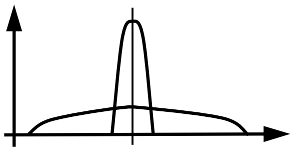
Code sharing



- The digital signal is multiplied with a so-called spreading code, and the result is to be transmitted
  - multiplication: NOT(XOR(bit1,bit2))
  - transmitted signal is added to the other signals transmitted by other mobiles
- The bitrate of the spreading code (chiprate) much greater (appr. 100x) than that of the „useful" signal
- The spreading codes are orthogonal, that is the average of multiplication of any two spreading codes is 0

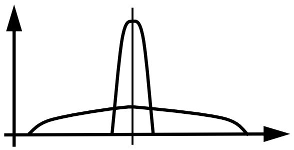


Code sharing

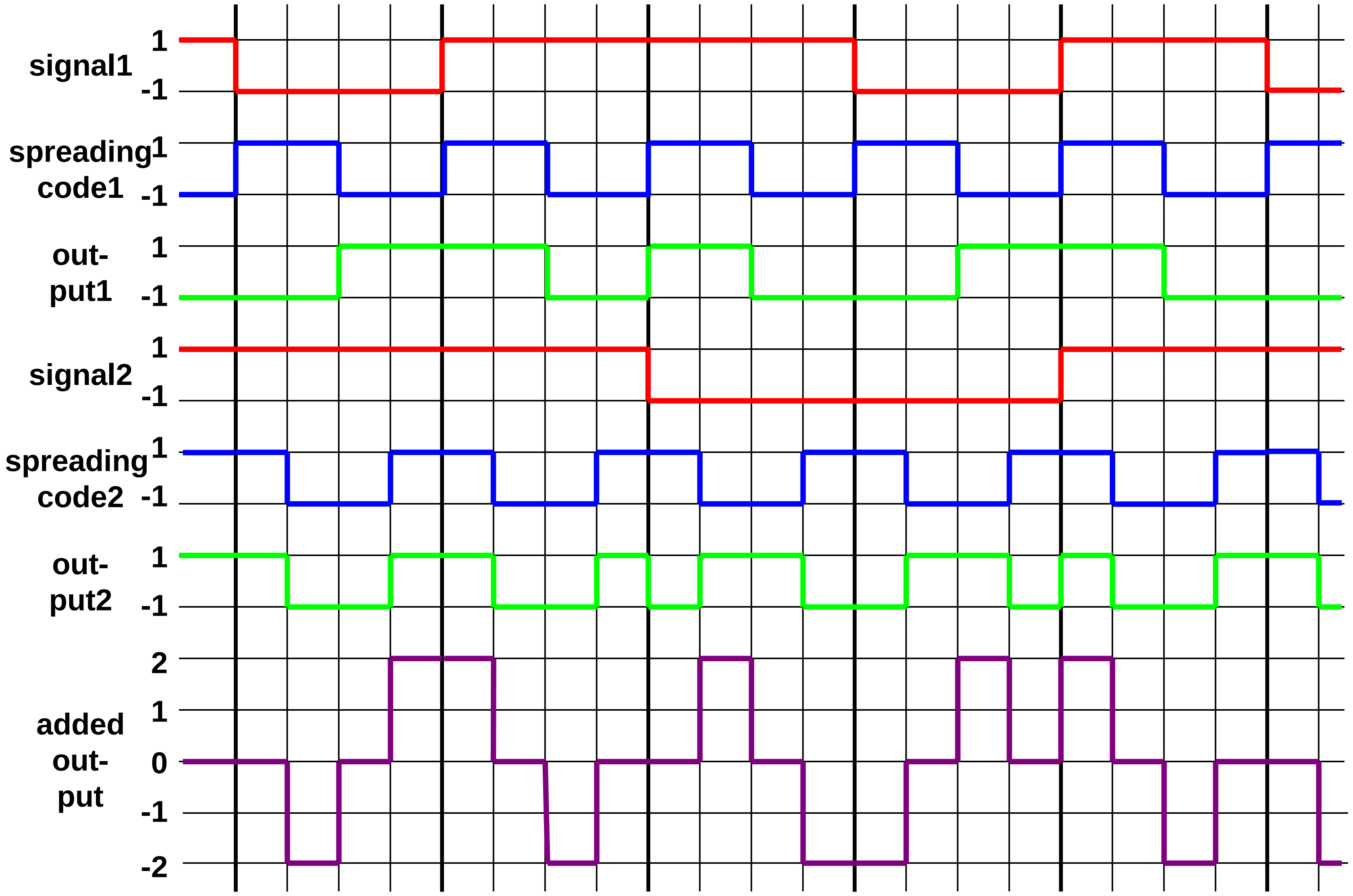


- A bit more detailed:
- Encoding
  - STEP 1. Let us represent the bits of the spreading code and the bits of the data to be encoded in the following way:
    - 1 → 1
    - 0 → -1
    - Recognise: this case NOT(XOR(a,b)) is actually a*b
      - 1*1=1, 1*-1=-1, -1*1=-1, -1*-1=1
  - STEP 2. Let us multiply the spreading code with the data to be transmitted
    - multiply *every* bit of the spreading code with *one* bit of the data (this way the signal speed increases remarkable)
  - STEP 3. Let us transmit the multiplied signal on the common frequency
    - In our model we simply add all the signals
- Decoding
  - STEP 1. Let us multiply the received signal (sum of STEP 3 of encoding) with the bits of the spreading code of the transmitter. (As many times, as many bits we want to receive.)
  - STEP 2. Let us average the values calculated this way for (data) bit durations
  - STEP 3. If average 1: sent bit 1. If average -1: sent bit 0
  - STEP 4. Let us do this for every receiver

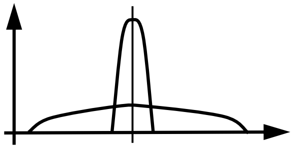
Code sharing



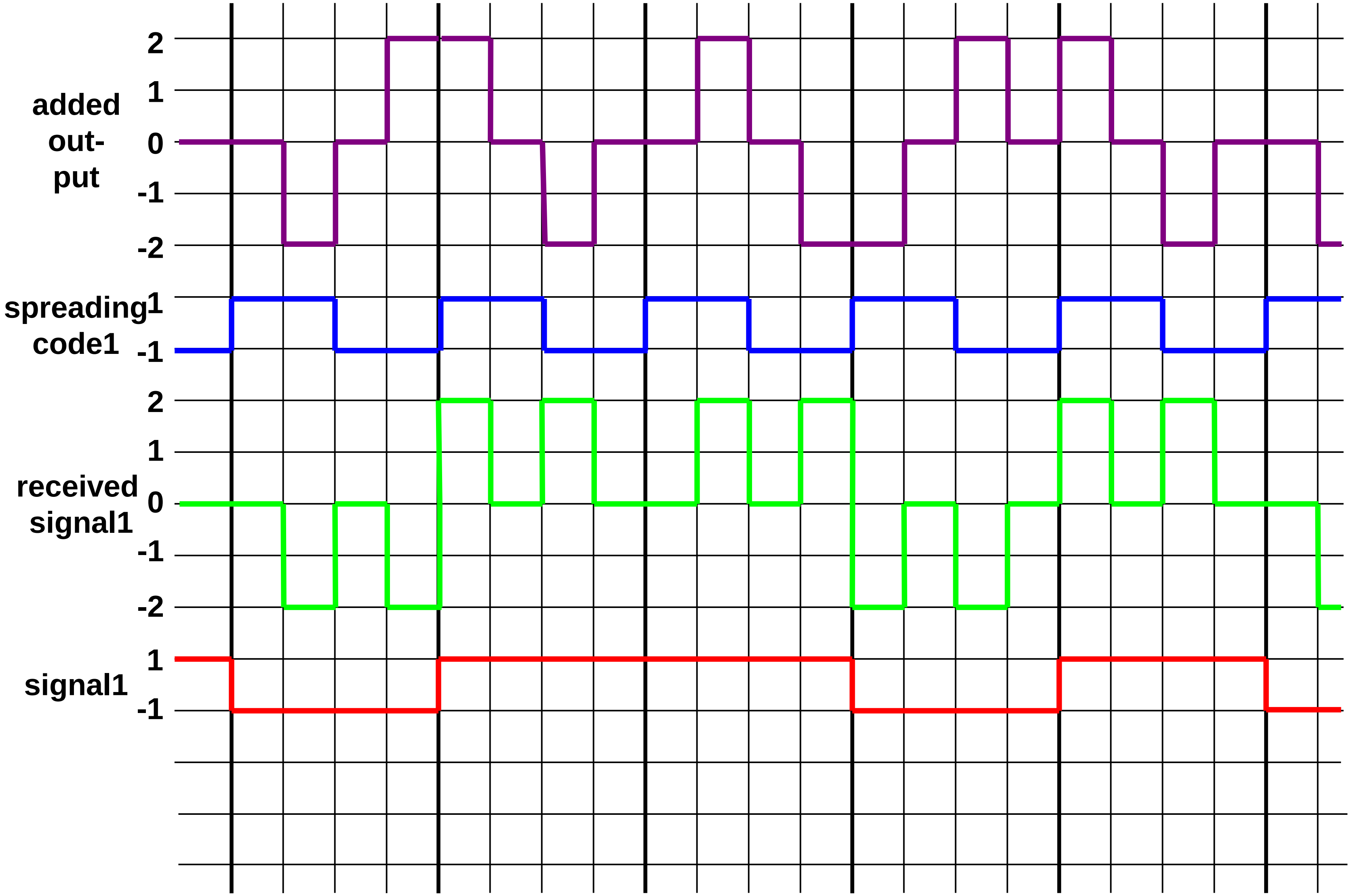
- Example for encoding:



Code sharing



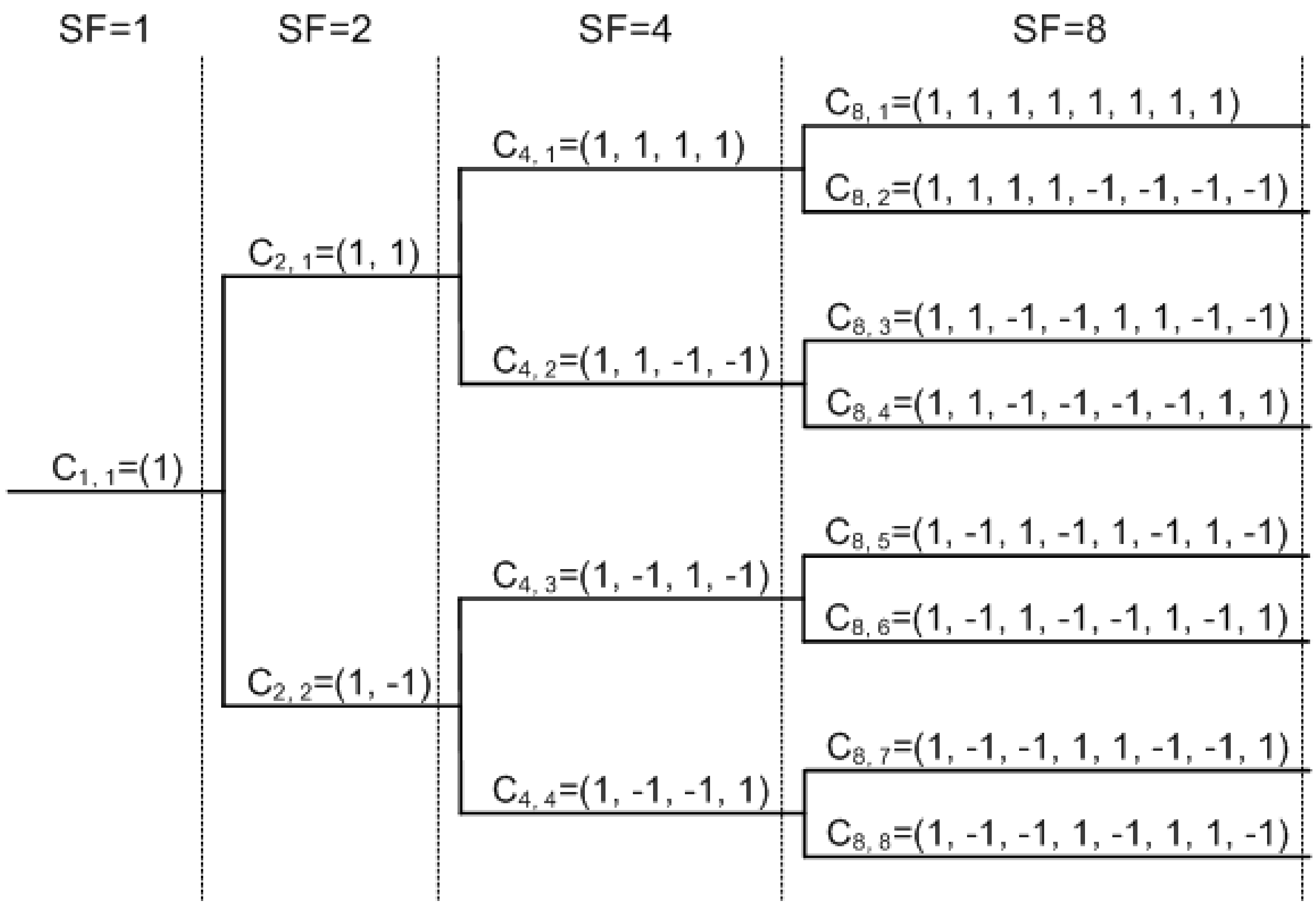
- Example of decoding:



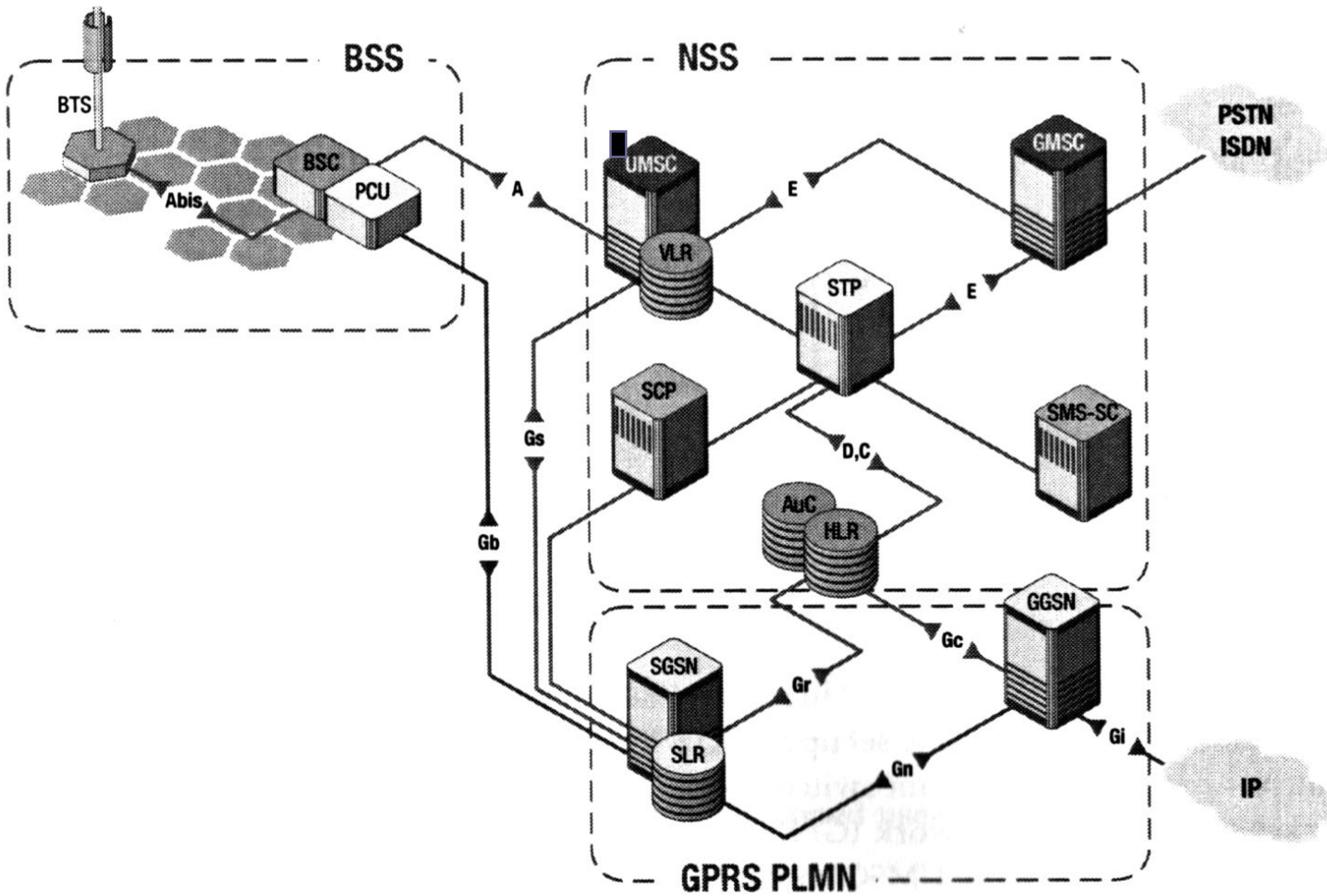
Code sharing

- Let us see a numerical example!
  - Let us transmit the signals (1, 0) and (1, 1) with using the (1, 1, 0, 0), and (1, 0, 0, 1) spreading codes
- Encoding:
  - STEP 1. Data signals are:
    - A: (1, -1)
    - B: (1, 1)
  - STEP 1. The two spreading codes are:
    - A: (1, 1, -1, -1)
    - B: (1, -1, -1, 1)
  - STEP 2. Signals to be transmitted:
    - A: 1,1,-1,-1,-1,-1,1,1
    - B: 1, -1, -1, 1, 1, -1, -1, 1
  - STEP 3. Sum of them:
    - 2, 0, -2, 0, 0, -2, 0, 2
- Decoding
  - STEP 1. The multiplication:
    - A: 2, 0, 2, 0, 0, -2, 0, -2
    - B: 2, 0, 2, 0, 0, 2, 0, 2
  - STEP 2. Averages:
    - A: 1, -1
    - B: 1, 1
  - STEP 3: Received signals:
    - A: 1, 0
    - B: 1, 1
- Comment: we could do this, because the spreading codes are really orthogonical, that is the average of the multiplication of the two spreading codes is really 0:
  - The multiplication of the two spreading codes: 1, -1, 1, -1
  - The average: 0

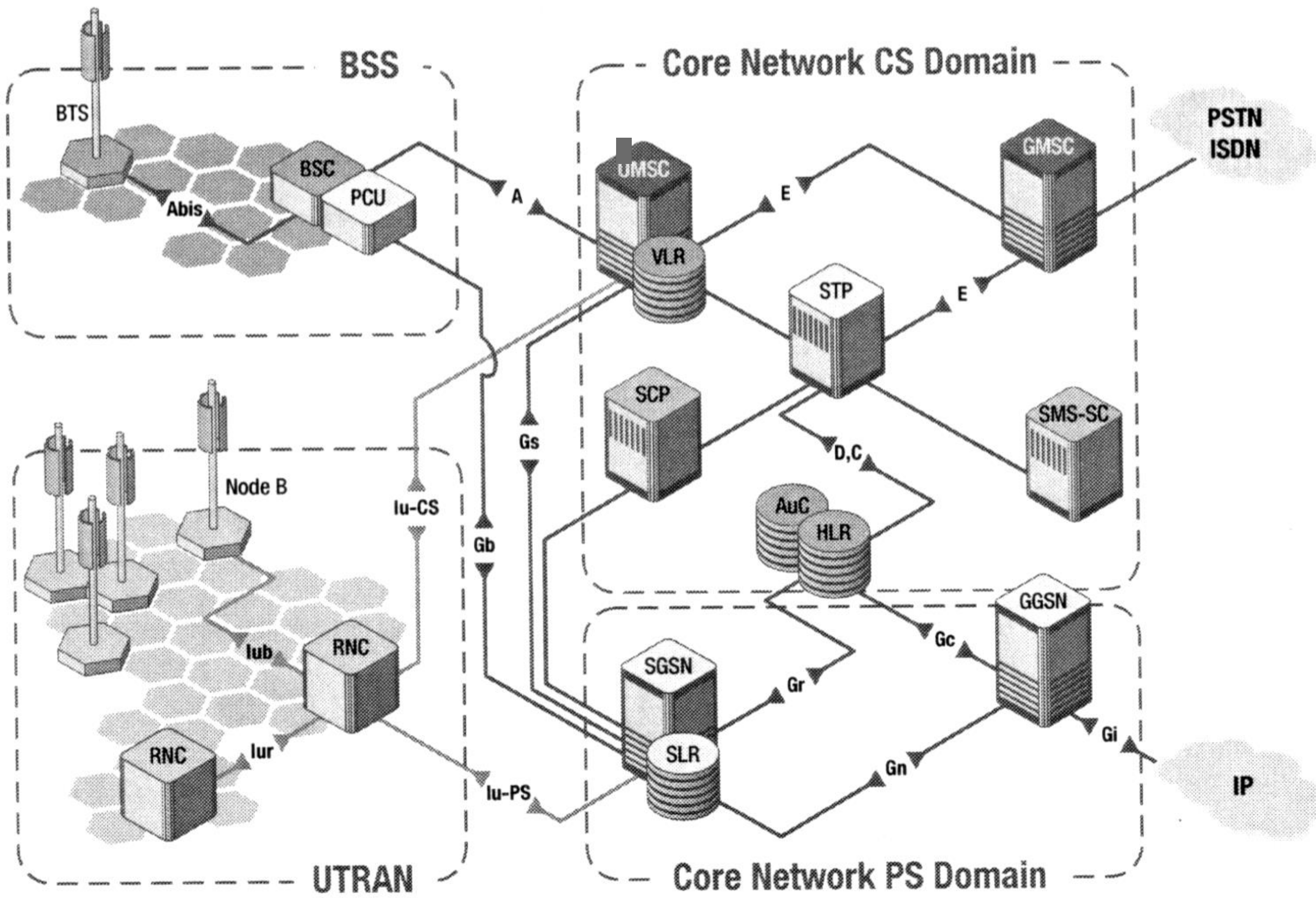
Spreading code generation



GSM/GPRS architecture („2,5G”)

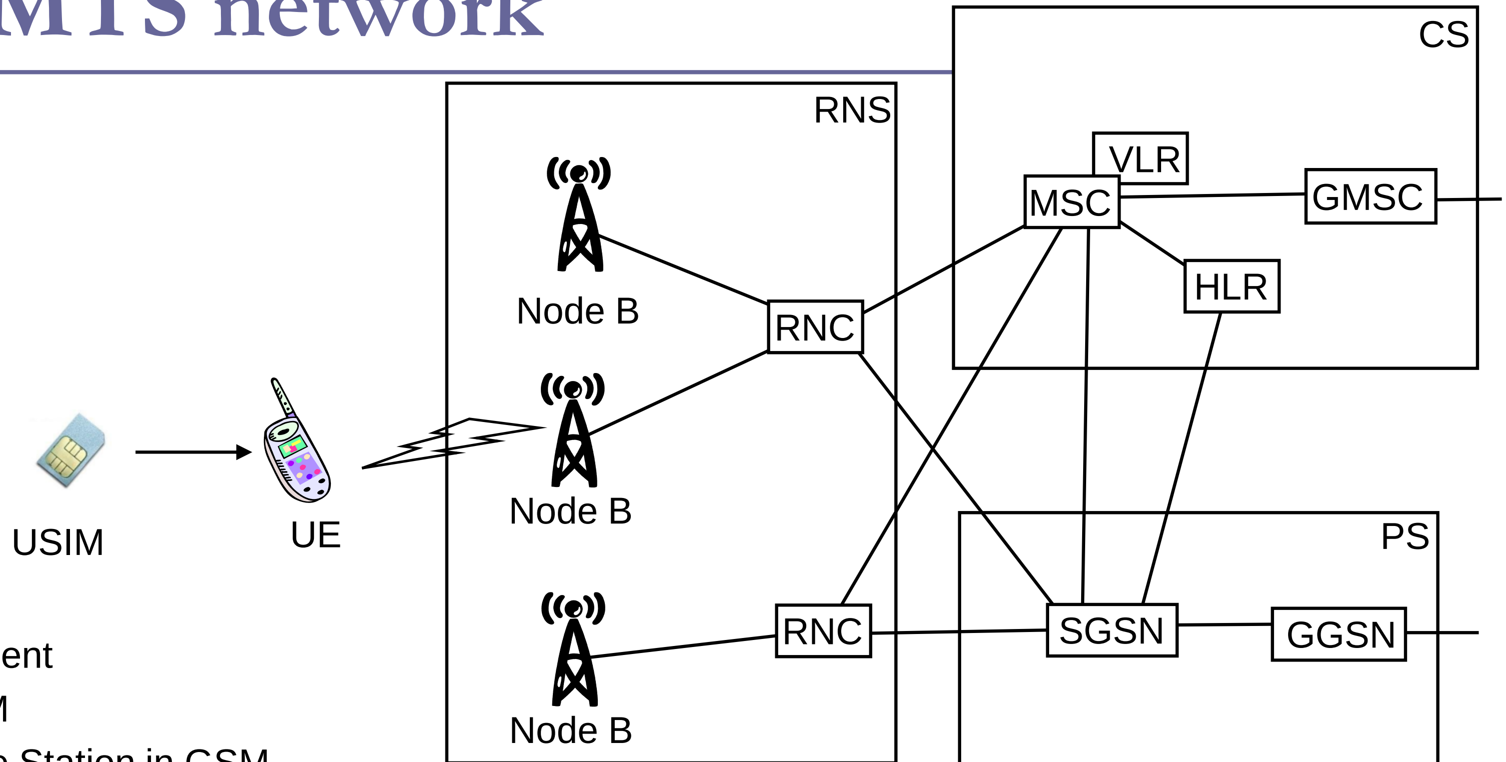


UMTS R’99 architecture



UTRAN: Universal/UMTS Terrestrial Radio Access Network

The UMTS network

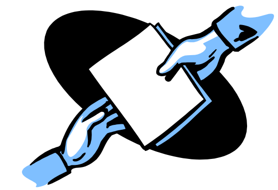


UE: User Equipment
USIM: UMTS SIM
Node B: like Base Station in GSM
RNC: Radio Network Controller, (like BSC in GSM)
RNS: Radio Network Subsystem
MSC, HLR, VLR: same as in GSM
GMSC: Gateway MSC: MSC and gateway to other network(s) (e.g. ISDN)
CS: Circuit Switched subsystem
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node: packet switch and gateway to other network(s) (e.g. Internet)
PS: Packet Switched subsystem
UMTS Relase 99: Core Network ~ GSM+GPRS, Radio IF different

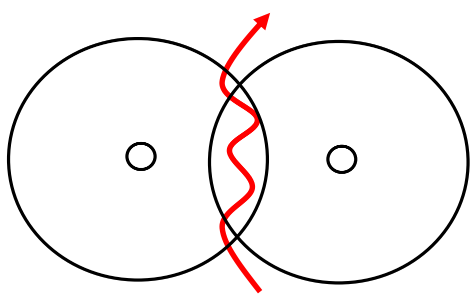
Duplexity management in UMTS

- Separate the uplink and downlink data
- The possible solutions:
  - in time
  - in frequency
- Both used in UMTS (but not at the same time)
  - FDD: Frequency Division Duplexing
    - higher frequency in downlink direction (larger attenuation → larger power needed)
  - TDD: Time Division Duplexing
    - advantage: the ratio of the up- and download can be dynamically changed according to the current needs
    - (ping-pong method)

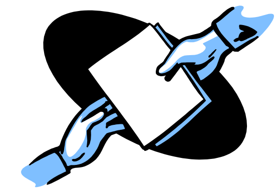
Handover – circuit switched



- GSM: hard handover
  - MS communicates with either base station then, in the next time slot with the other one
  - the handover is as fast as it can be
    - But appr. 20 samples/data units are lost
  - cell change with hysteresis: to reduce the number of handovers in the case when the MS moves at the boundaries of the cells

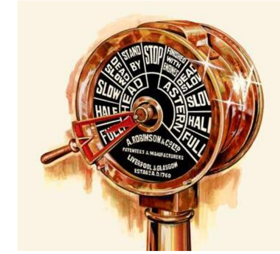


UMTS soft handover



- UMTS: soft handover
  - UE is in contact with more (max. 3) base stations
  - downlink data (the same) is transmitted by all of them – so the UE receives it from several sources
    - so if something is lost from a given base station it can be replaced from the others
  - uplink data (the same) is received by every base station
    - the network assembles the pieces of data received by the different base stations – so if data is lost in a cell it may be corrected by those received in the other cells
  - this connection to several base stations can last a relatively long time
- The redundancy is important, because we are at the edge of the cell, where the receive is the worst
  - but redundant transmission requires a bit of waste of bandwidth
- The code sharing makes it possible:
  - same frequencies in neighbouring cells

UMTS power control

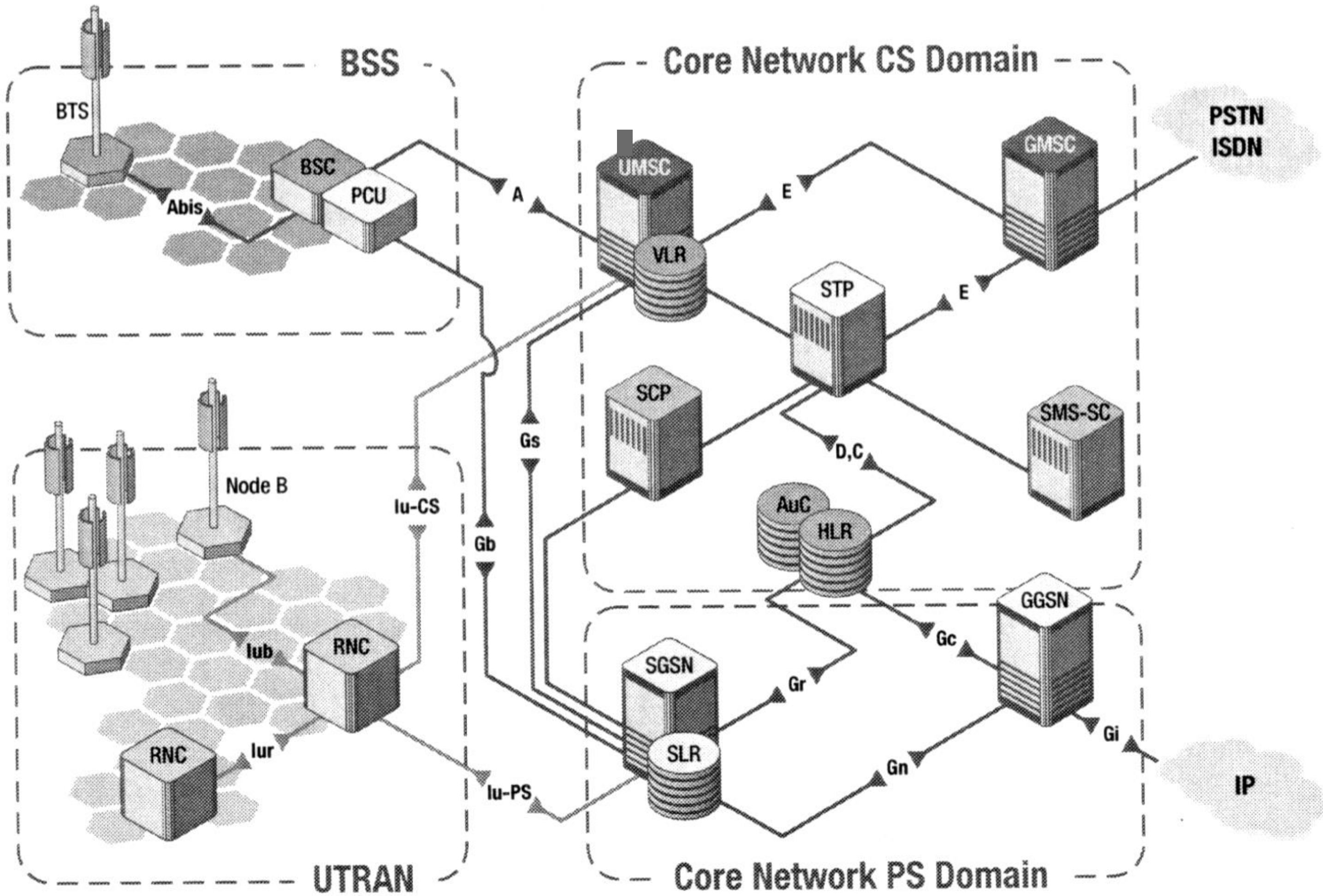


- The orthogonality of the applied spreading codes is not perfect
- In a base station when receiving the signal of a UE, the signals of the other UEs appear to be noise
  - (no such a problem in downward direction, since only the Node B transmits)
- So the signal of every UE must arrive to the Node B with the same power
  - otherwise the strongest suppresses all the others
- Solution: Node B orders the UEs to reduce/increase the transmission power
- 1500 times/sec (!)
  - Else e.g. a UE comes out from the shadow of a building (till that time transmitting with great power) will destroy the communication of the whole cell
- While in GSM:
  - to reduce the usage of batteries, to reduce the physiological risks
  - to avoid interference with far cells using the same frequency
  - 2 times/sec (!)

UMTS cell breathing

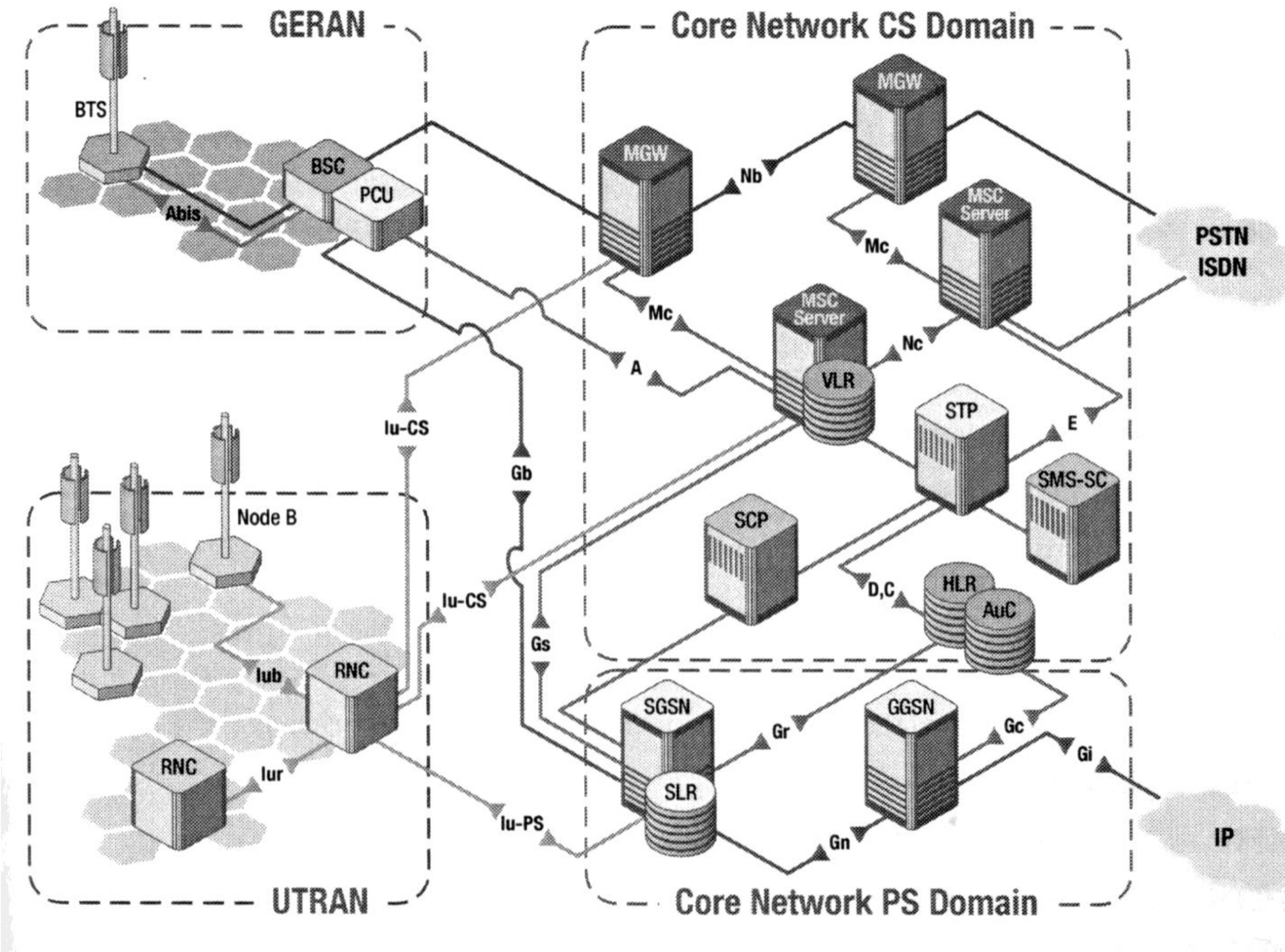
- More users in a cell
- $\rightarrow$ bigger „background noise”
- $\rightarrow$ smaller is the effective size of the cell
  - the far UE should transmit with larger than the maximal power
- $\Rightarrow$ the size of the cell depends on the traffic
  - cell is „breathing”
- makes the design of the cell structure more complicated

UMTS R'99 architecture



UTRAN: Universal/UMTS Terrestrial Radio Access Network

UMTS R4 architecture

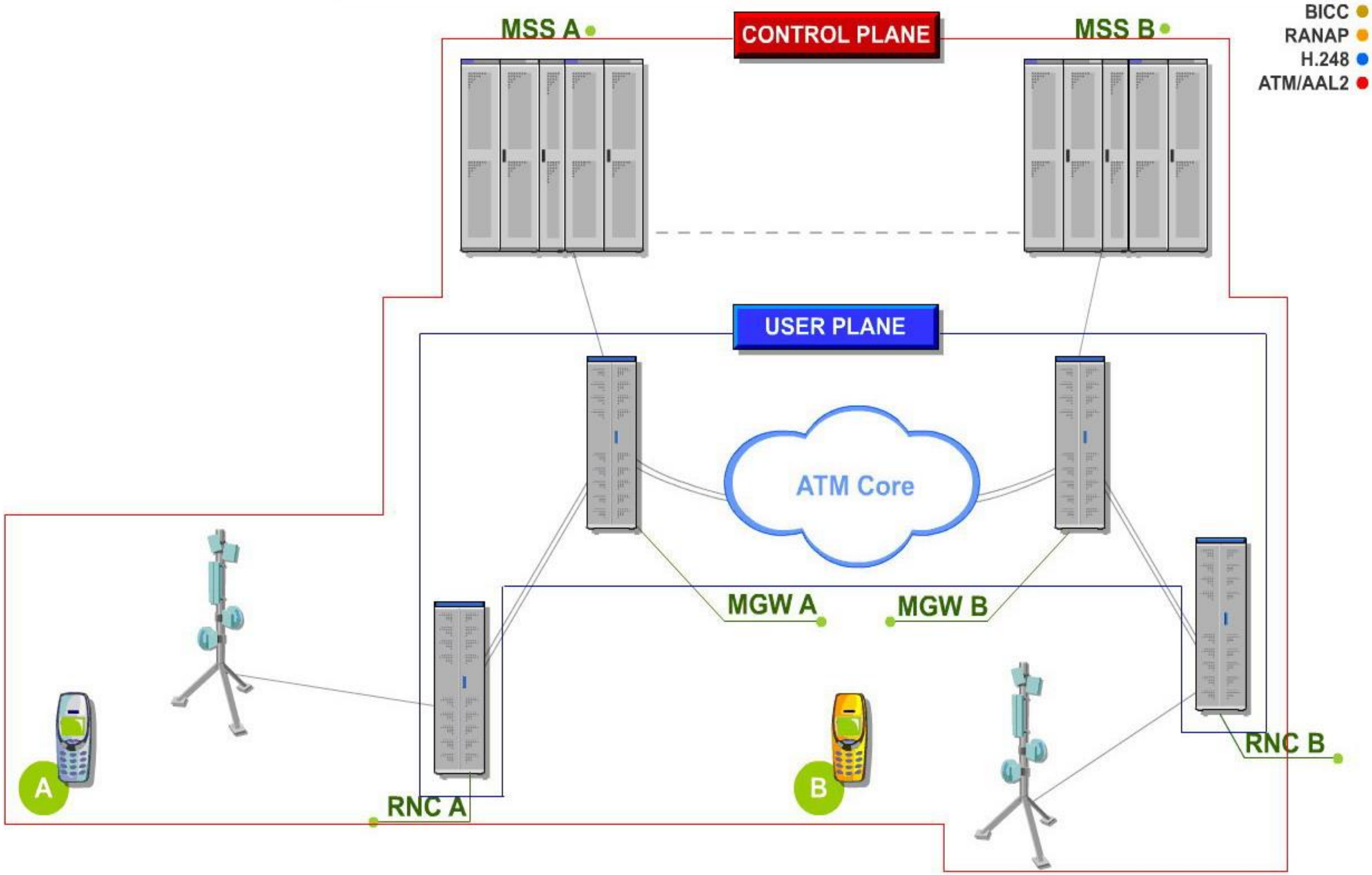


GERAN: GSM EDGE Radio Access Network

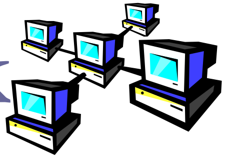
Separation of functions of switches

- (G)MSC Server [(G)MSS] is responsible for:
  - Signaling (call control)
  - Mobility Management (together with VLR)
- MGW – Media Gateway is responsible for :
  - Transmission of user traffic (voice, data) within core network
  - Protocol conversion towards
    - Radio access network (UTRAN, GERAN)
    - PSTN/ISDN
    - Previous mobile networks (Before Rel 4)
  - Goal: to be able to use any protocol between MGWs
  - IP or ATM
    - az MGW is actually an ATM switch or an IP router

UMTS Release 4 – Control/User Plane



Future: All IP UMTS core network



- Originally UMTS core: ATM
- Now: All IP core network:
  - Advantages of IP core:
    - More services
    - More flexible
    - Cheaper
    - MGW (VoIP!!) and SGSN can be integrated
  - Disadvantages of IP core:
    - An other signal conversion is needed
    - Reliability is not yet obvious