Communication Networks

VITMAB06

Mobile Networks 3G - UMTS

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UMTS (3G)

*A typical 3G phone: SonyEricsson Z610i (2006)
Small, pretty, colorful, push button. It had no operating system, Java applications (games) could be run on it*

3G

- ITU has specified what a 3G system must know
  - ITU = International Telecommunication Union (global, not only European)
  - e.g. min. 200 kb/s data transfer rate
- 3GPP: 3rd Generation Partnership Project standardised
    - www.3gpp.org
- Two common implementations
  - UMTS (Universal Mobile Telecommunications System)
    - Europe, Japan, China, etc.
    - User Equipment compatible with GSM
    - Since 2001
  - CDMA2000
    - North America, South Korea
    - User Equipment compatible with cdmaOne (IS-95) 2G system
    - Since 2002

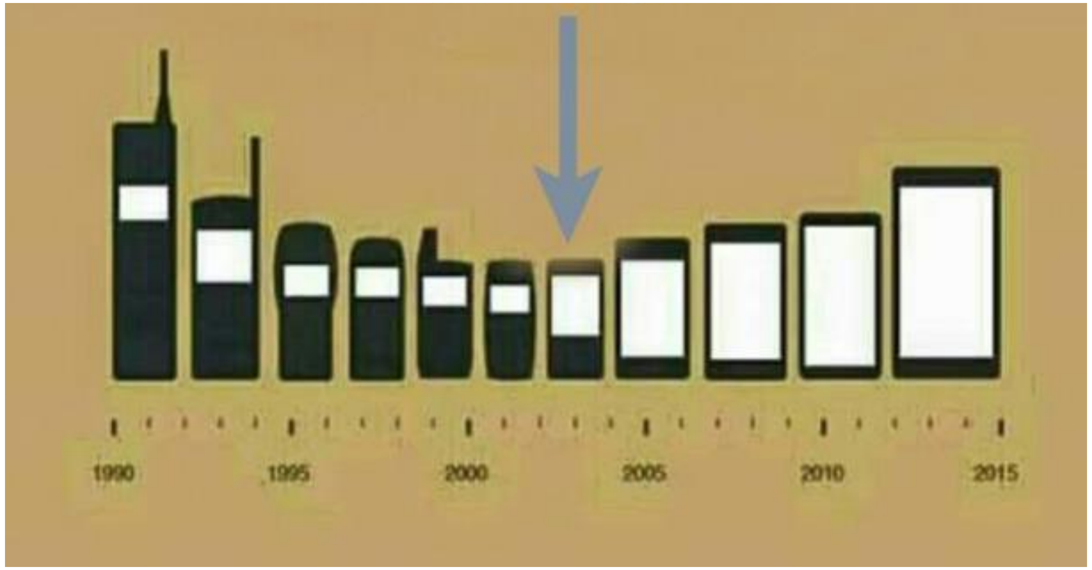
UMTS

- UMTS goals:
  - better quality of voice (same as in ISDN)
  - better utilisation of spectrum
  - higher data transmission speed
  - backward compatibility with GSM
    - 3G is a brand new network, but could have been introduced step-by-step

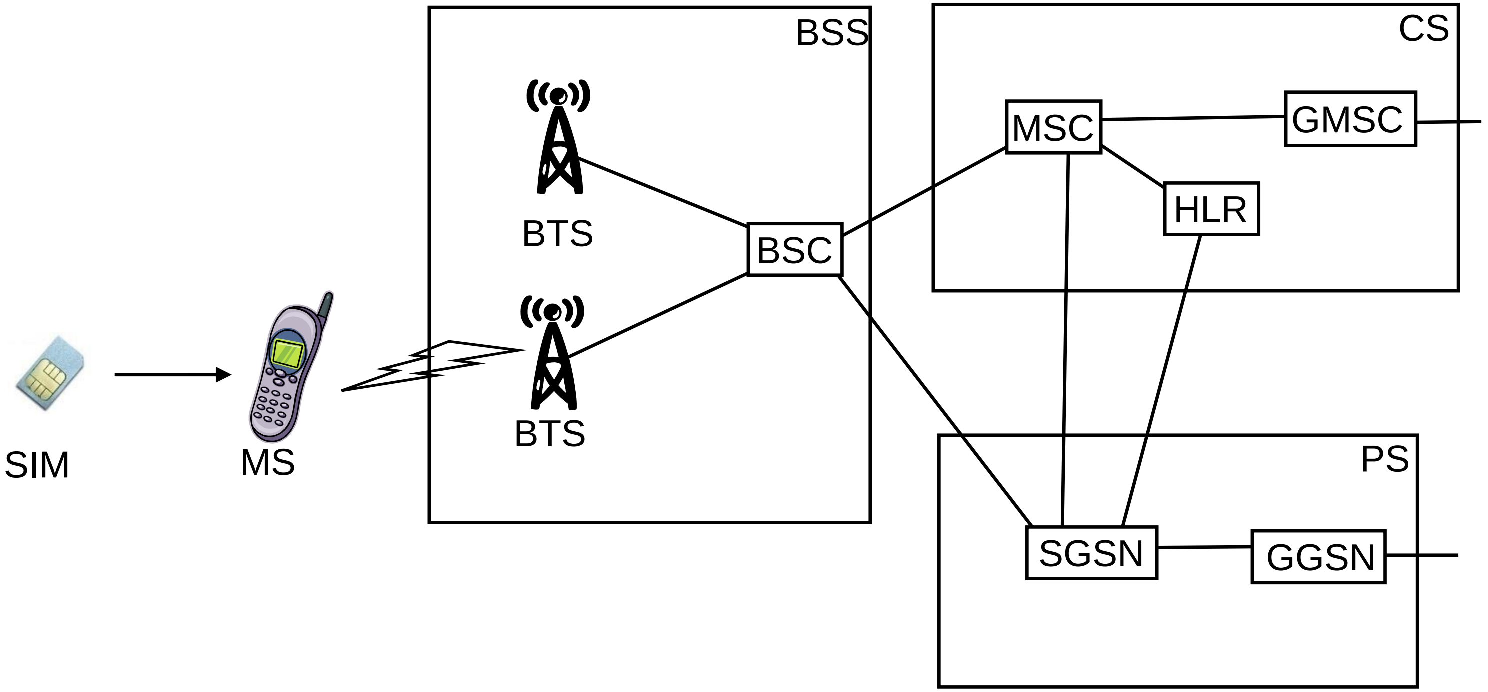
UMTS services

- Voice transmission:
  - Adaptive MultiRate (AMR) codec
  - 4,7 – 12,2 kb/s
- Data transfer, Internet acces (original 3G)
  - 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
    - (Reminder:
      - GSM: cca. 14 kb/s
      - GSM/GPRS: cca. 50-80 kb/s
      - EDGE+GSM/GPRS: cca. 150-180 kb/s)
- Multimedia services (without IP, directly over 3G)
  - Videotelephony – not too many users
  - Broadcasting TV shows, listening to radio, downloading movies, music - they didn't succeed
    - Not in a native way, but as applications over Internet
    - **The "killer" application of 3G is the high data speed**

3G



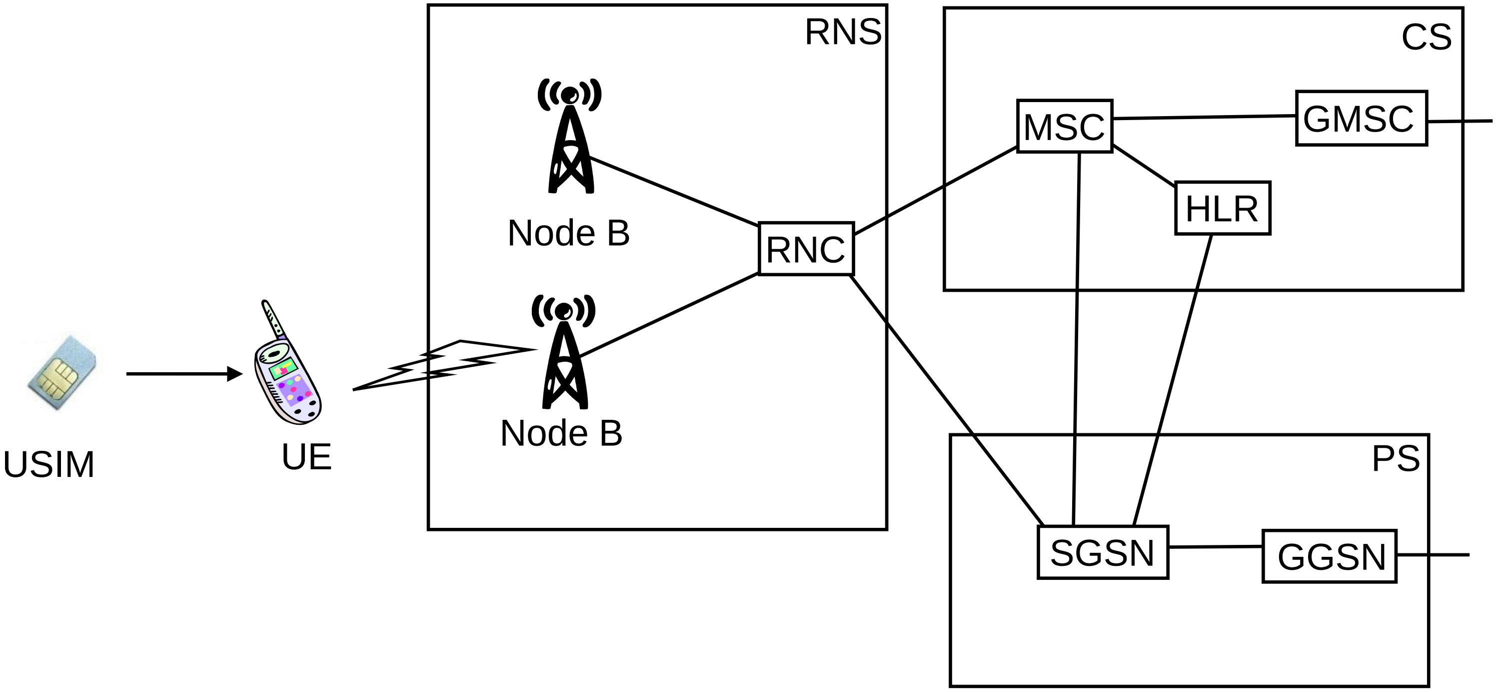
GSM/GPRS



SIM: Subscriber Identity Module
MS: Mobile Station
BTS: Base Transceiver Station
BSC: Base Station Controller
BSS: Base Station Subsystem
MSC: Mobile Switching Center
HLR: Home Location Register
GMSC: Gateway MSC

This part is oversimplified, just for illustration

UMTS



UE: User Equipment
USIM: UMTS SIM
Node B: similar to BTS in GSM
RNC: Radio Network Controller, (similar to BSC in GSM)
RNS: Radio Network Subsystem, similar to BSS in GSM
MSC, HLR, GMSC, SGSN, GGSN: same as in GSM
CS: Circuit Switched (Subsystem)
PS: Packet Switched, (Subsystem)

This part is oversimplified, just for illustration

Differences mainly at radio, NSS remained (almost) the same

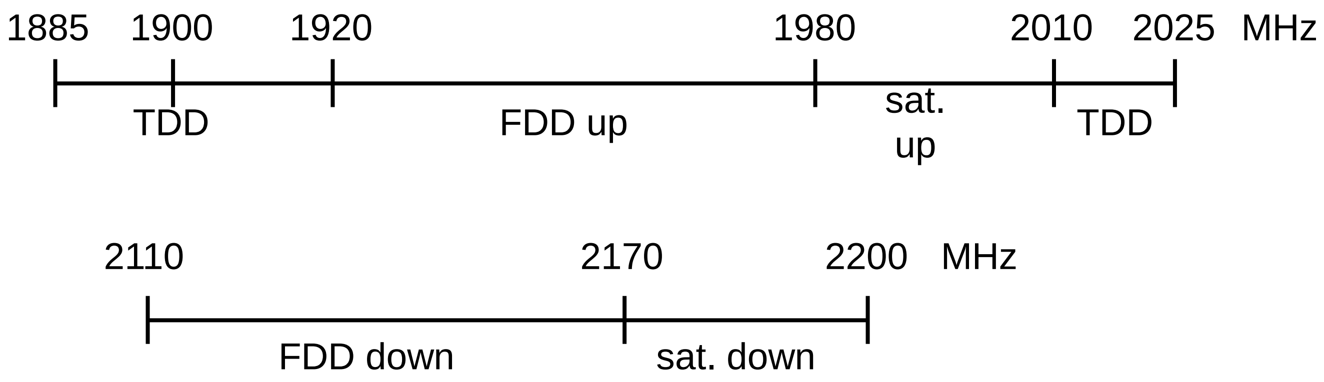
Duplexity management in UMTS

- To 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 downlink traffic can be dynamically changed according to the current needs
    - (ping-pong method)
    - WHY??
      - Most of the data traffic is asymmetric (e.g. browsing)
      - Typical symmetric services: voice, most of the P2P (e.g. gaming)

Radio access in UMTS

Specific frequency ranges do not need to be learned, enough to know it is ~2MHz

- Frequencies:
  - 1885-2025 and 2110-2200 MHz:
    - TDD: 1885-(1900-)1920 MHz and 2010-2025 MHz
    - FDD: 1920-1980 (up) and 2110-2170 (down)
    - satellite (remained only a plan): 1980-2010 MHz (up) and 2170-2200 MHz (down)
  - High frequency: only several (1-5) km diameter cells
  - The frequencies are divided into 5 MHz channels, in which CDMA is used
    - one service provider a few channels, different service providers different channels

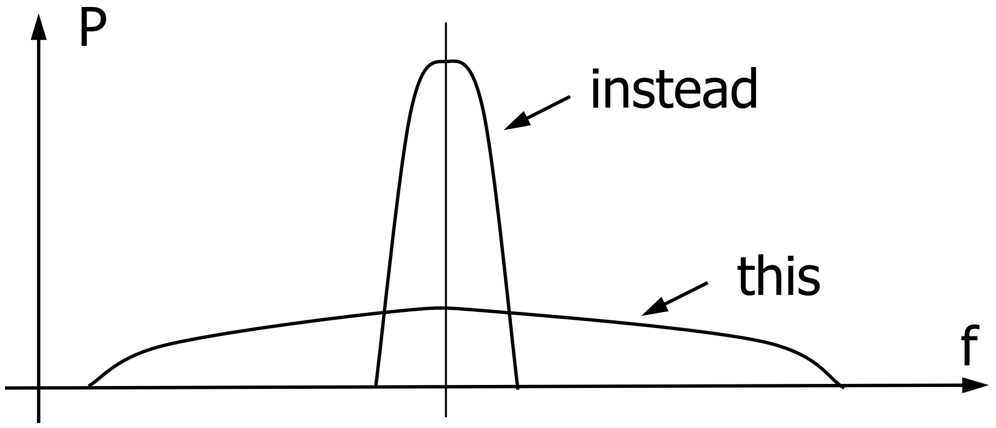


What is close to it?

(Microwave ovens, 2.45 GHz)

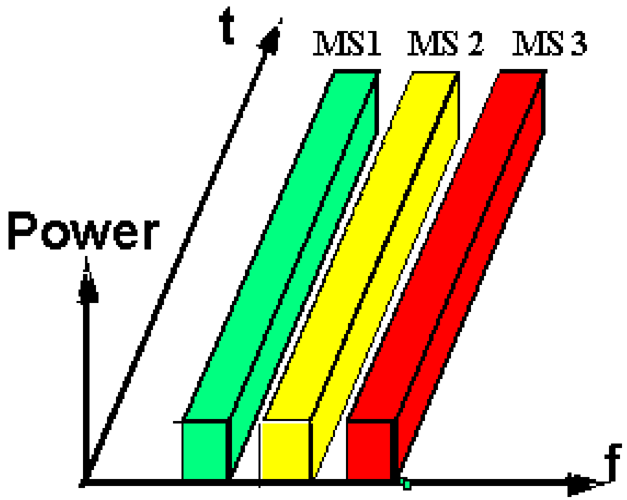
Radio access in UMTS

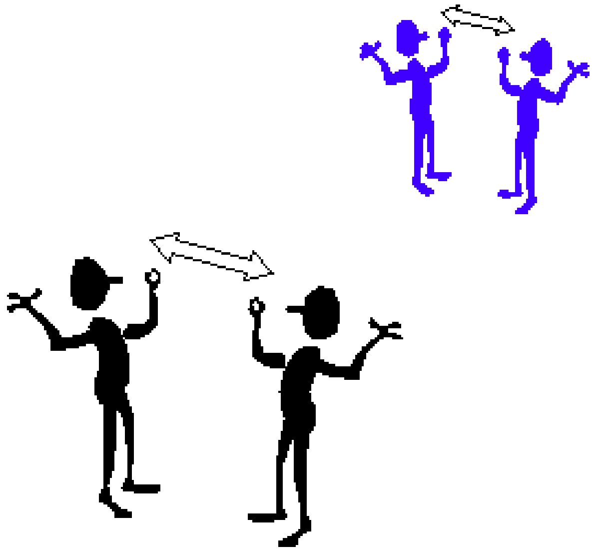
- *CDMA*, Code Division Multiple Access
- Same frequency, same time, different code
  - like: multilanguage airport lobby
- Every signal is spread in the whole spectrum, but with small power
- Goal: better utilisation of the spectrum



FDMA – Frequency Division Multiple Access

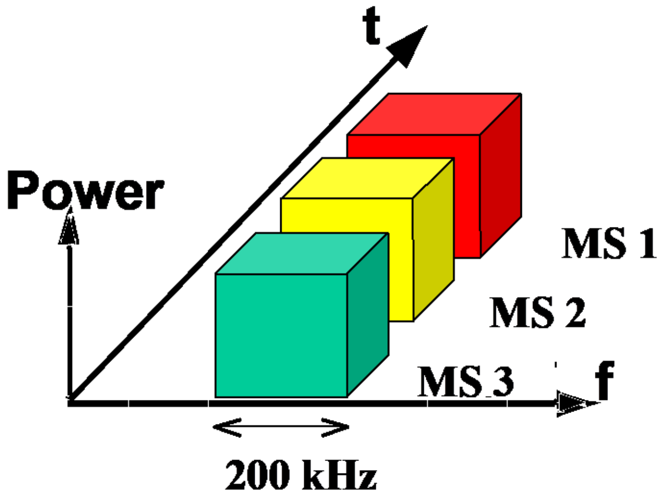
- Orthogonal in frequency within cell
- Narrow bandwidth per carrier
- Continuous transmission and reception
- No synchronization in time





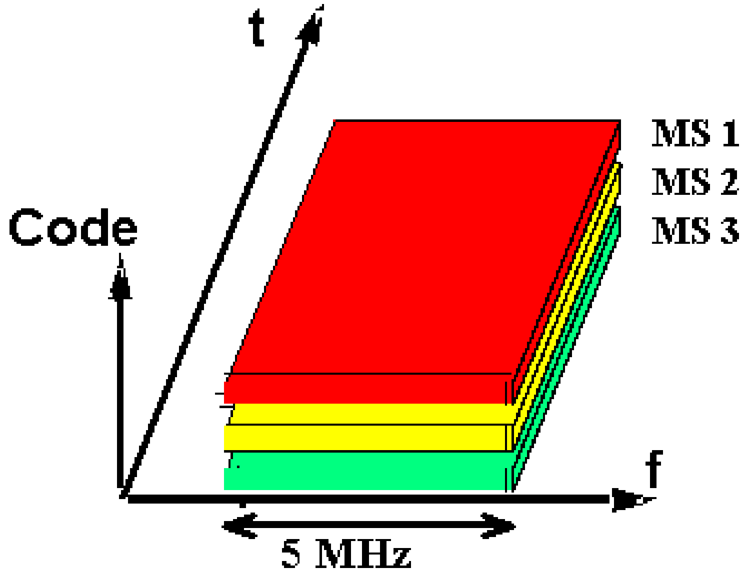
TDMA – Time Division Multiple Access

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

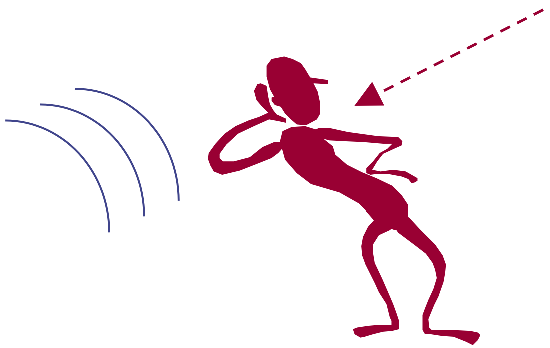


CDMA – Code Division Multiple Access

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

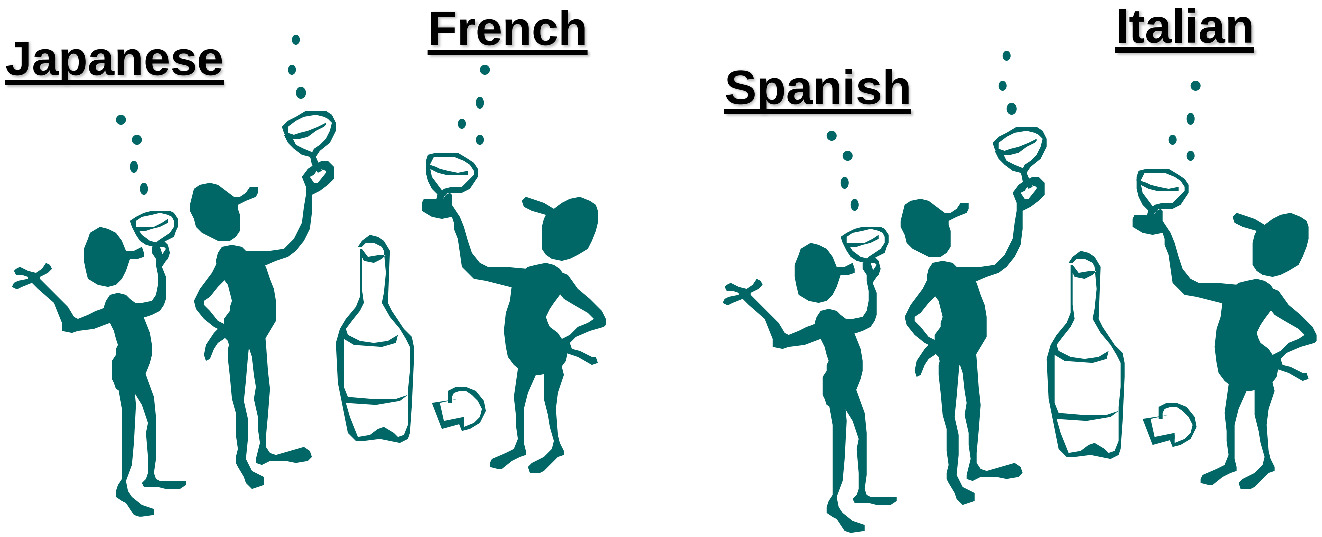


CDMA International Cocktail Party



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?

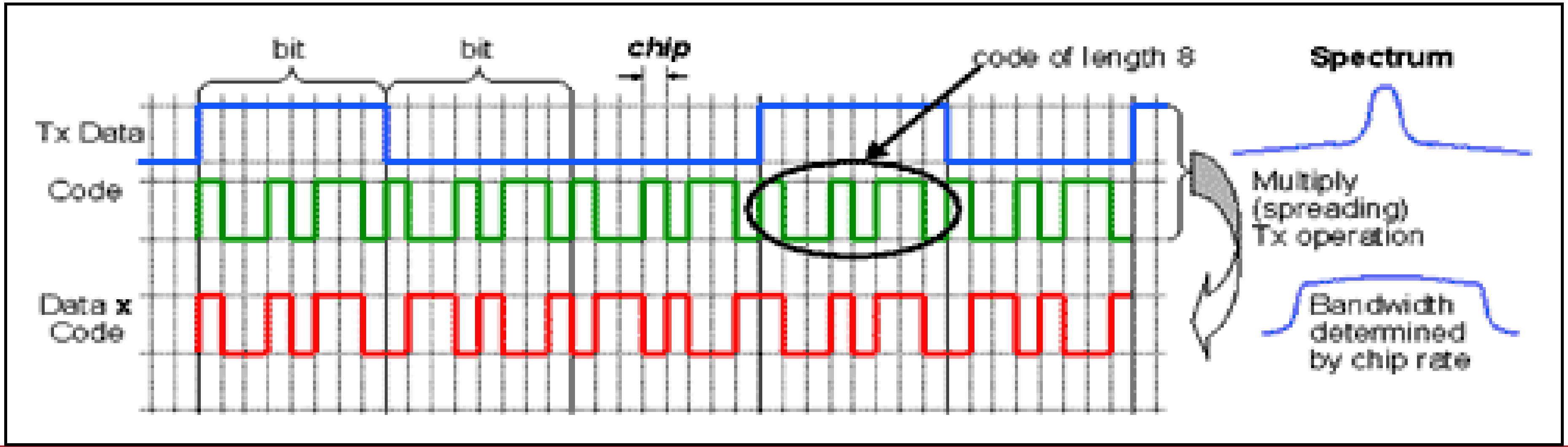


Code sharing

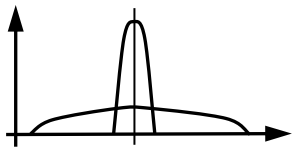
Since UMTS is (being) phased out, the details of the encoding is not taught, but only the basic idea

- 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

GSM still survives, funny, isn’t it?

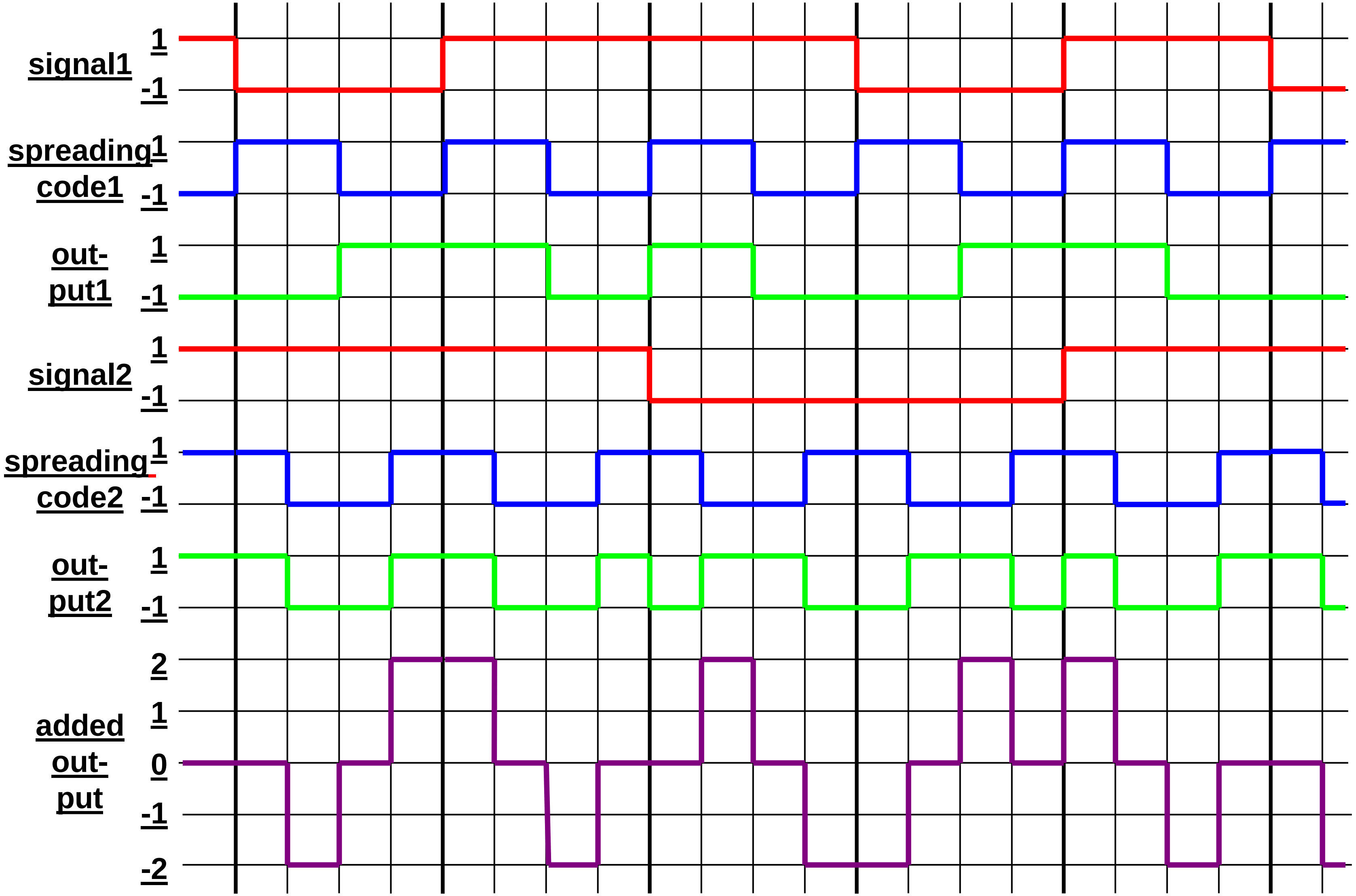


Code sharing

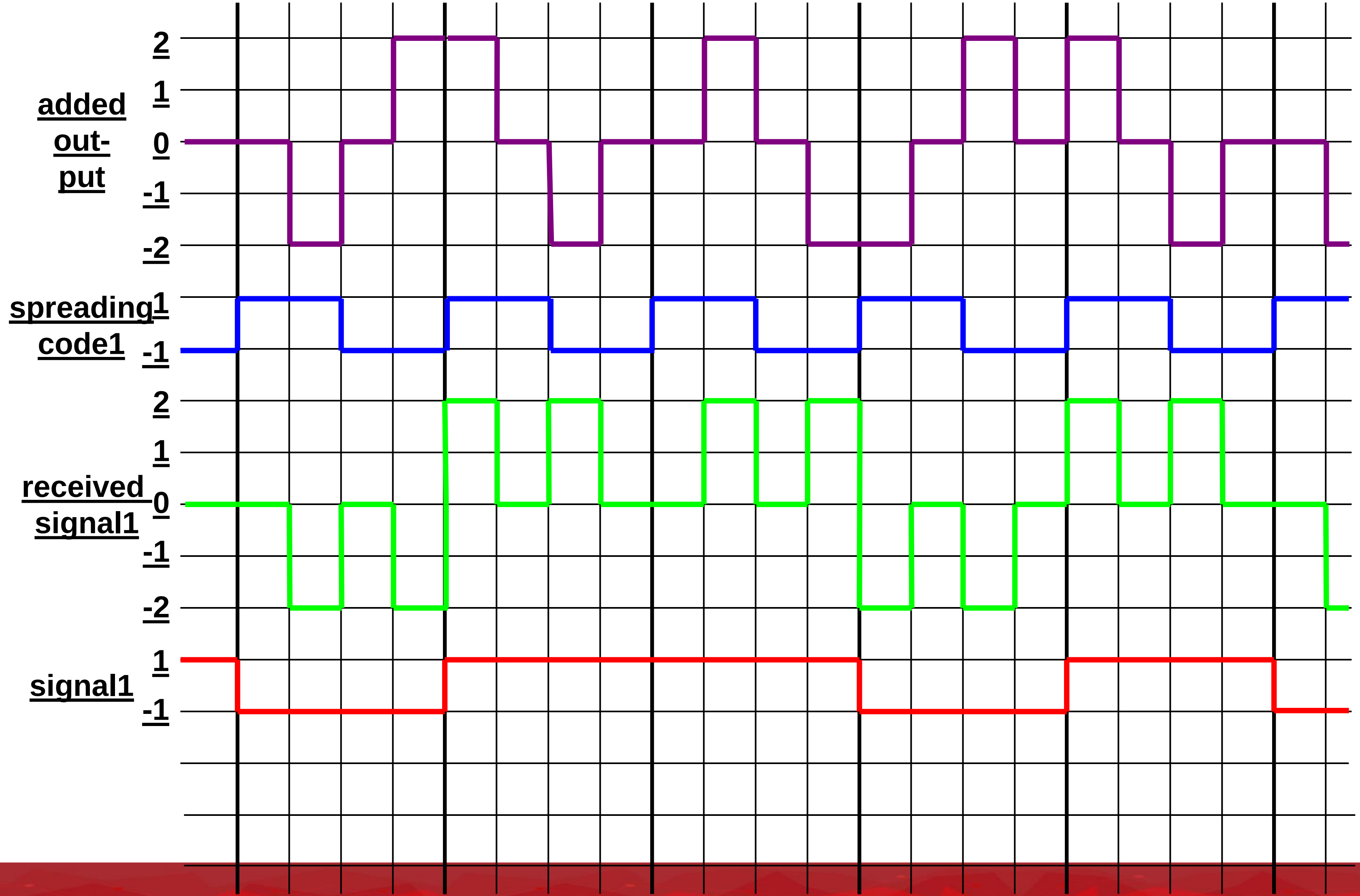


- Encoding
  - STEP 1. Let's represent the bits of the spreading code and the bits of the data to be encoded this way:
    - $1 \to 1$
    - $0 \to -1$
    - Recognise: in this case NOT(XOR(a,b)) is actually a*b
      - 1*1=1, 1*-1=-1, -1*1=-1, -1*-1=1
  - STEP 2. Let us multiply the spreading code with 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 spreading code (for all the connections)

Encoding example

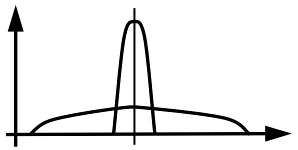


Decoding example



Code sharing

Just an illustration, not needed to be known, only the 'graphical' examples of previous slides



- 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 orthogonal, 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

UMTS power control

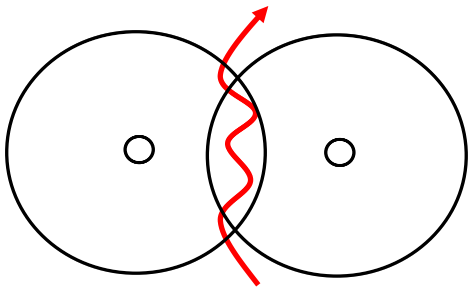
- The orthogonality of the applied spreading codes is not perfect
- In a base station when receiving the signal of a UE, the signals of the other UEs appear to be noise
  - (No such problem in downward direction, since only the Node B transmits)
- So, the **signal of every UE must arrive to the Node 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
  - Of if the UE moves fast (e.g. on a high-speed train)
- 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

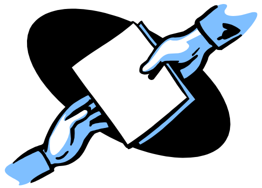
- More users in a cell
- $\rightarrow$ bigger „background noise"
  - because the spreading codes are not perfectly orthogonal
- $\rightarrow$ smaller is the effective size of the cell
  - stations that are far away from Node B are excluded
    - since they must not transmit with larger than the maximal power to overcome the noise
- $\Rightarrow$ the size of the cell depends on the traffic
  - cell is „breathing"
- makes the design of the cell structure more complicated

Handover – circuit switched

- GSM: hard handover
  - at one moment the mobile station communicates with one base station, and at the next with an other base station
  - 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



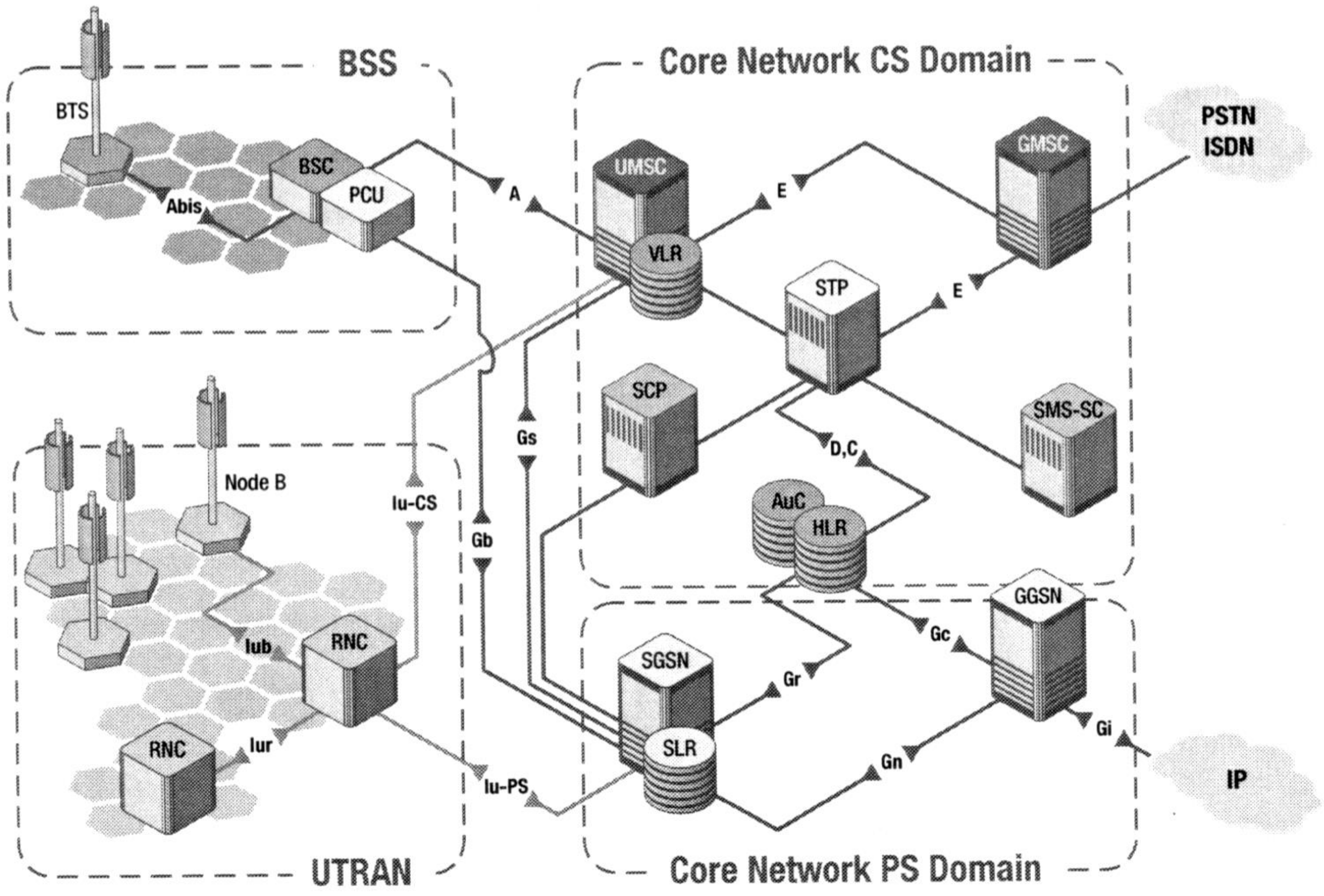
- UE is in contact with more (max. 3) base stations
  - Downlink data (the same) is transmitted by all of them – so the UE receives it from several sources
    - So, if something is lost from a given base station it can be replaced from the others
  - Uplink data (the same) is received by every base 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 receiving is the worst
  - But redundant transmission in downlink direction causes a bit of waste of bandwidth
- The code sharing is what makes it possible:
  - Same frequencies in neighbouring cells

Power control at soft handover

- UE in soft handover may receive different power controlling commands from the different Node Bs:
  - increase/keep/decrease the power
- The rule:
  - If anybody orders to decrease: UE decreases
  - Otherwise, if anybody orders to keep: UE keeps
  - Otherwise, UE increases
- The idea: to transmit with minimal power, so as not to destroy communication in any cell
  - However, from the above algorithm, it comes that the performance will be sufficient at least in one cell

UMTS R’99 architecture

You do not have to memorize the figure for the exam.



UTRAN: Universal/UMTS Terrestrial Radio Access Network

UMTS R4 architecture

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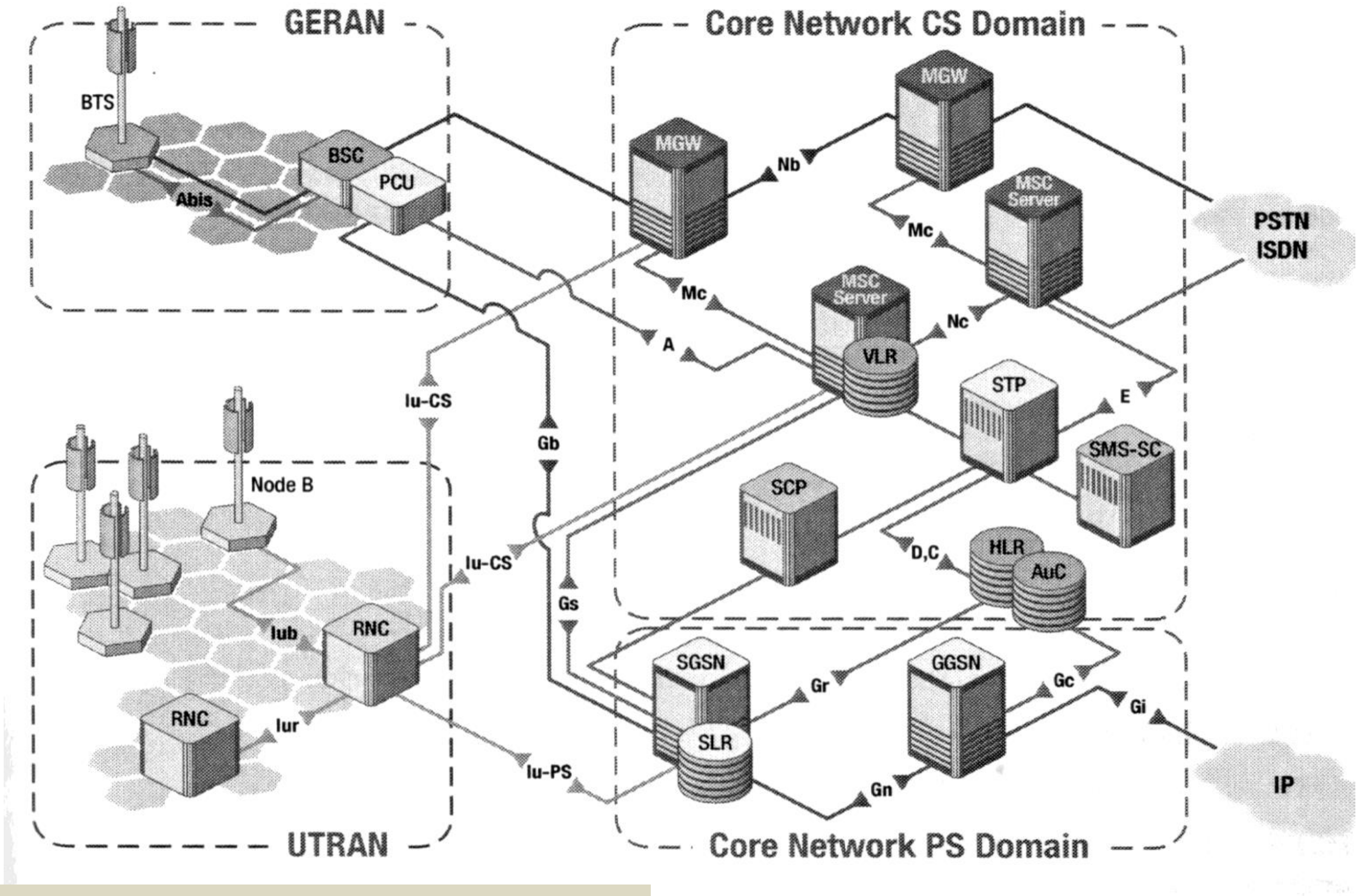

GERAN: GSM EDGE Radio Access Network

UMTS R4 architecture

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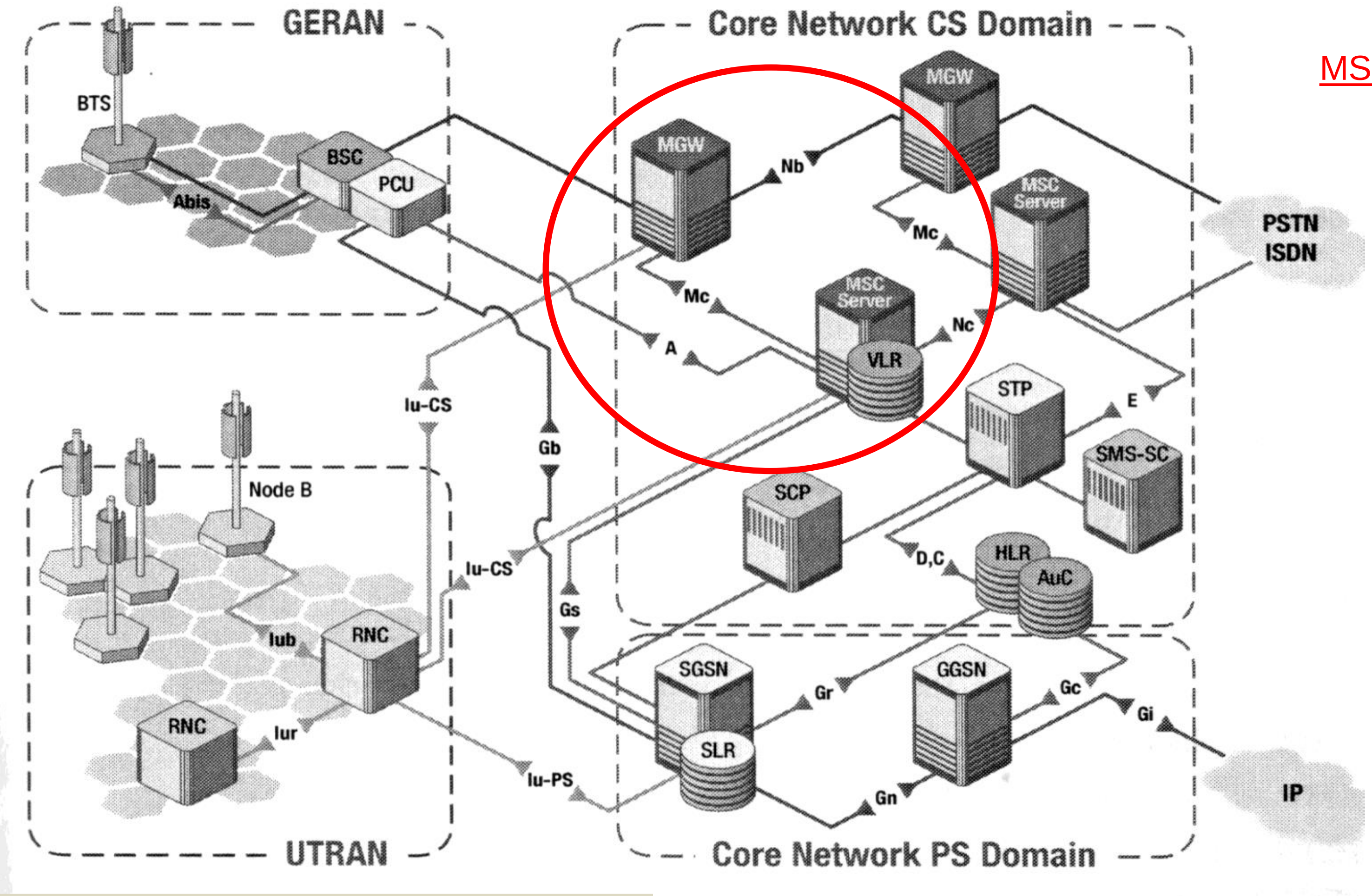


MSC -> MSC Server (MSS) + MGW

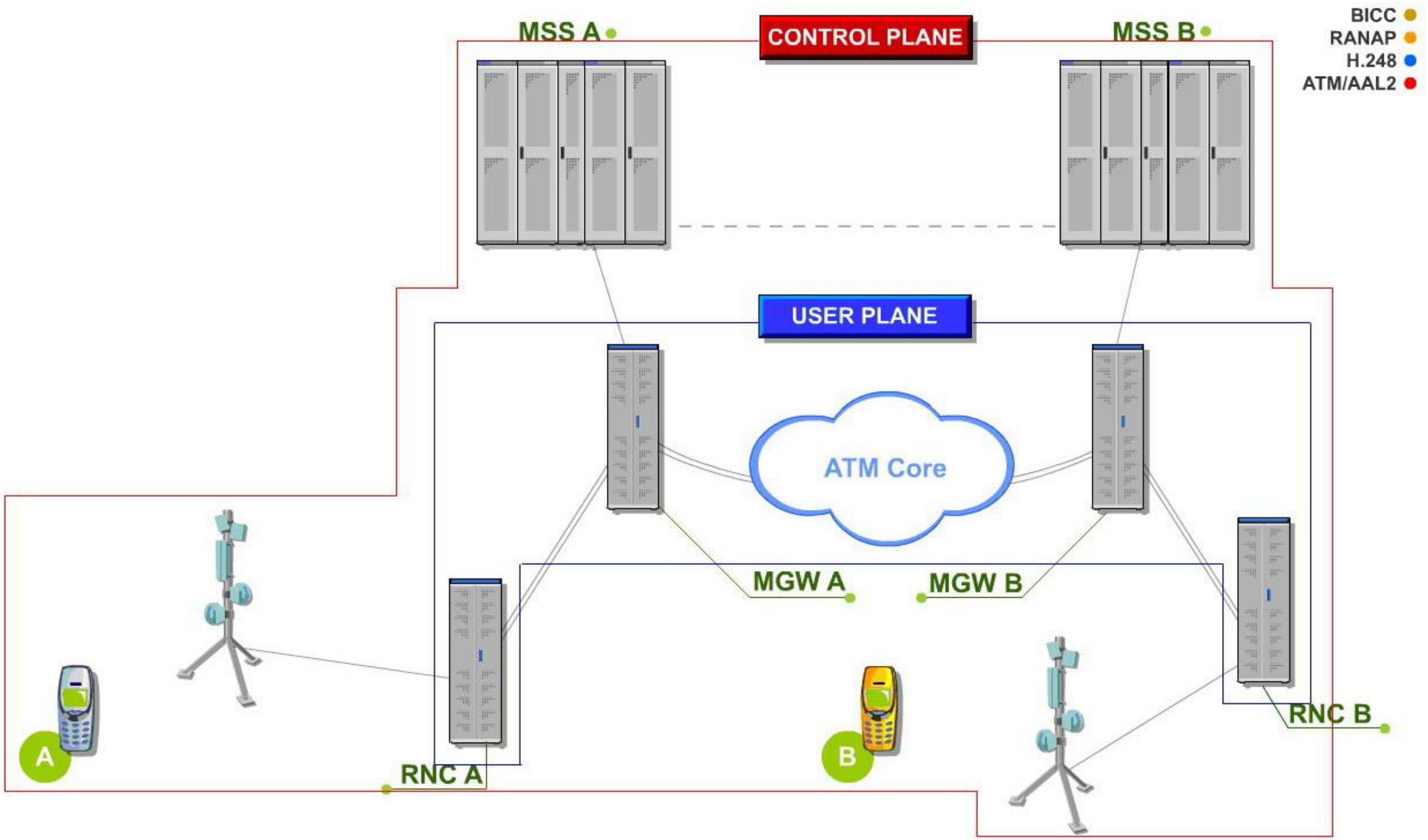
GERAN: GSM EDGE Radio Access Network

Separation of functions of switches

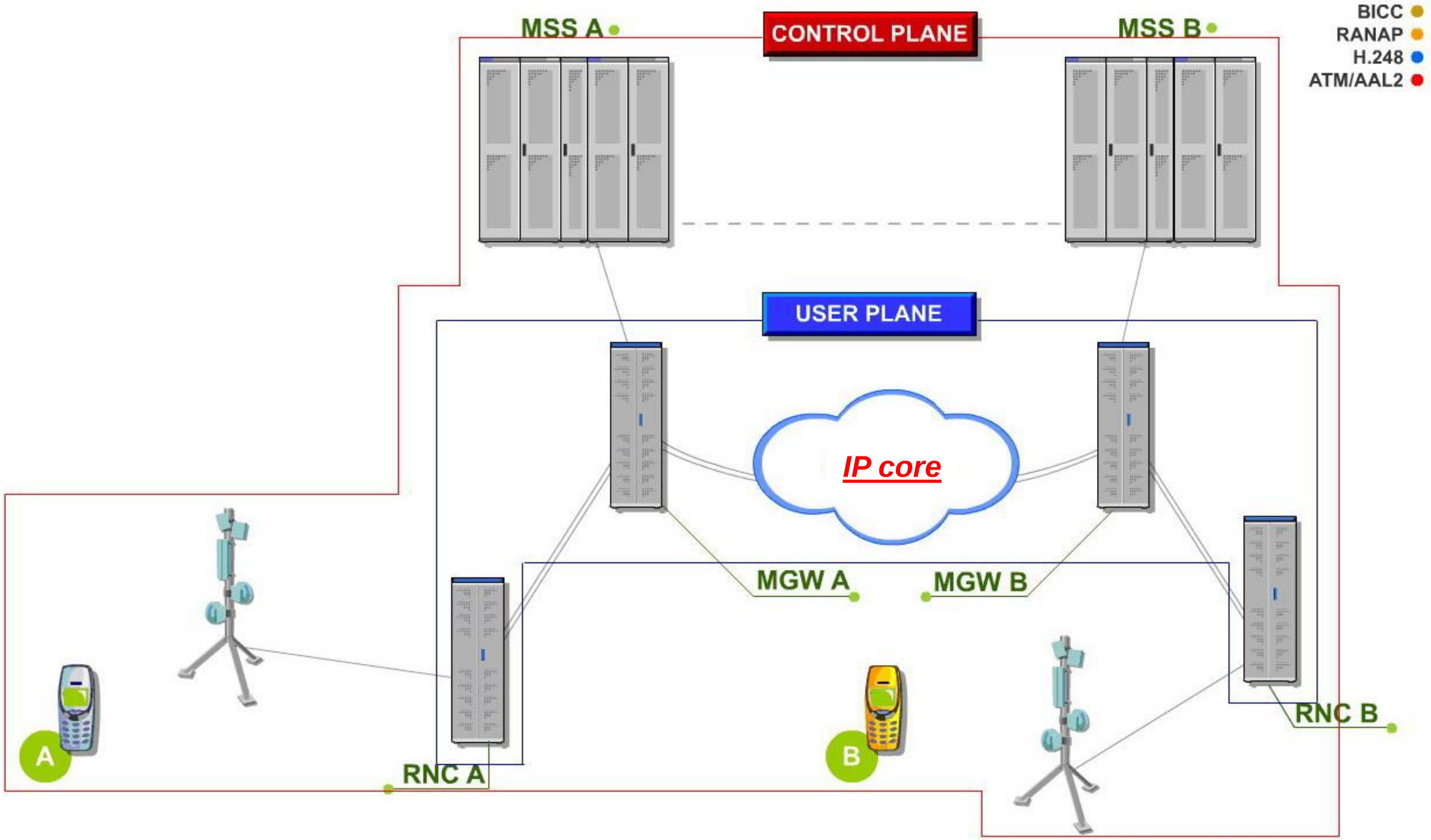
- (G)MSC Server [(G)MSS] is responsible for:
  - Signaling (call control)
  - Mobility Management (together with VLR)

- 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
  - ATM then IP
    - MGW is actually an ATM switch or an IP router
    - ATM: Asynchronous Transfer Mode

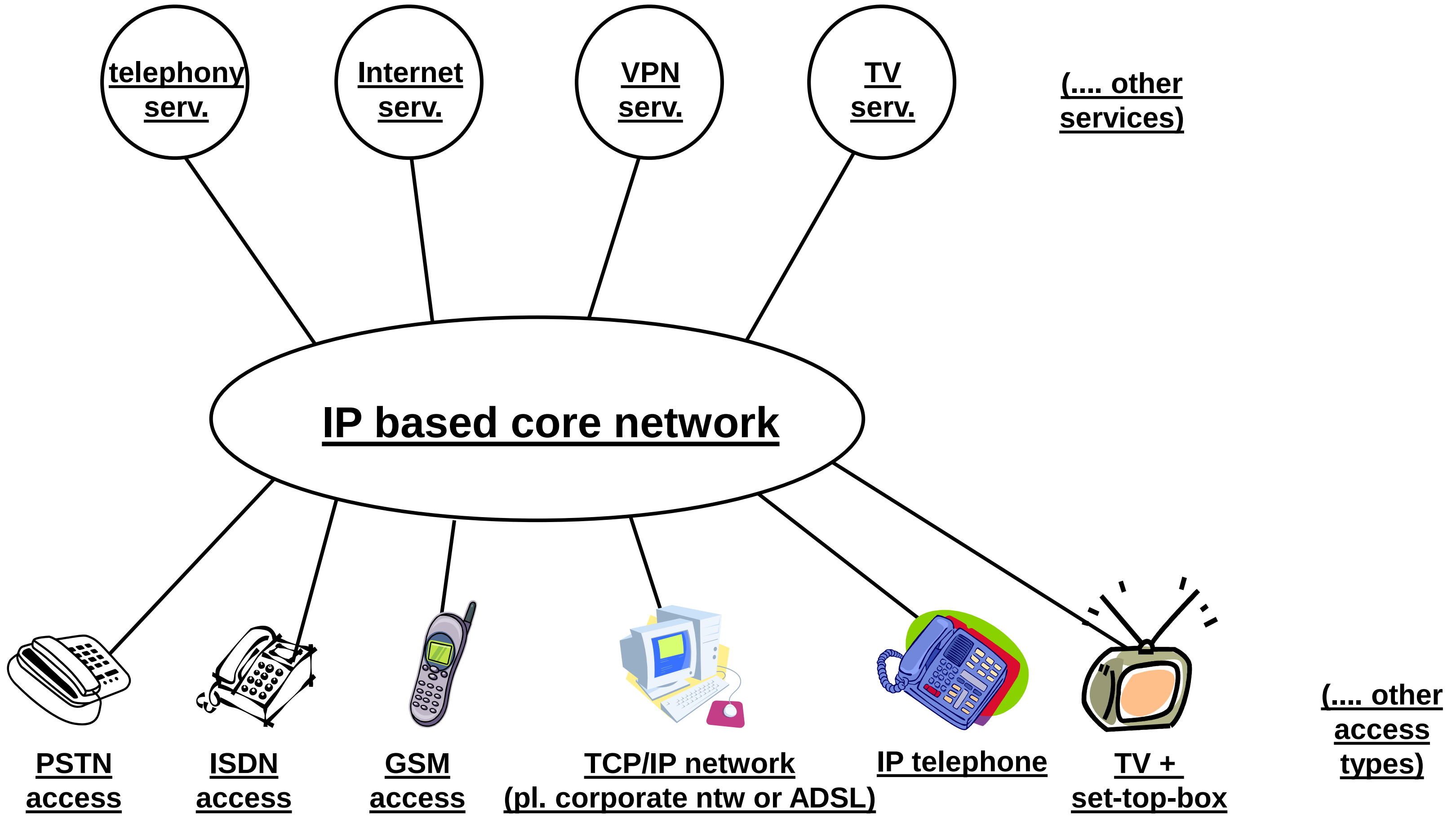
UMTS Release 4 – Control/User Plane



UMTS Release 4 – Control/User Plane



NGN architecture



UMTS summary

- Better voice quality
- Faster Internet access
- CDMA
- In later versions: all-IP core network: circuit switched (CS) backbone subnetwork is phased out
  - Only packed switched (PS) remains
- Development did not stop here: HSPA, HSPA+, LTE…

HSPA, HSPA+

- HSPA (High-Speed Packet Access)
- Further development of UMTS towards higher data speeds
- Common name of 2 protocols:
  - HSDPA (High Speed Downlink Packet Access)
    - Even up to 14 Mb/s
  - HSUPA (High Speed Uplink Packet Access)
    - Even up to 5,76 Mb/s
- It is part of UMTS, partly its further development
  - Often called as 3.5G
  - Introduced in the beginning of 2010s
- Next step: HSPA+
  - Theoretical max. 42 Mb/s down, 22 Mb/s up
  - „3.75 G”
  - Still acceptable, faster than of the first 4G systems