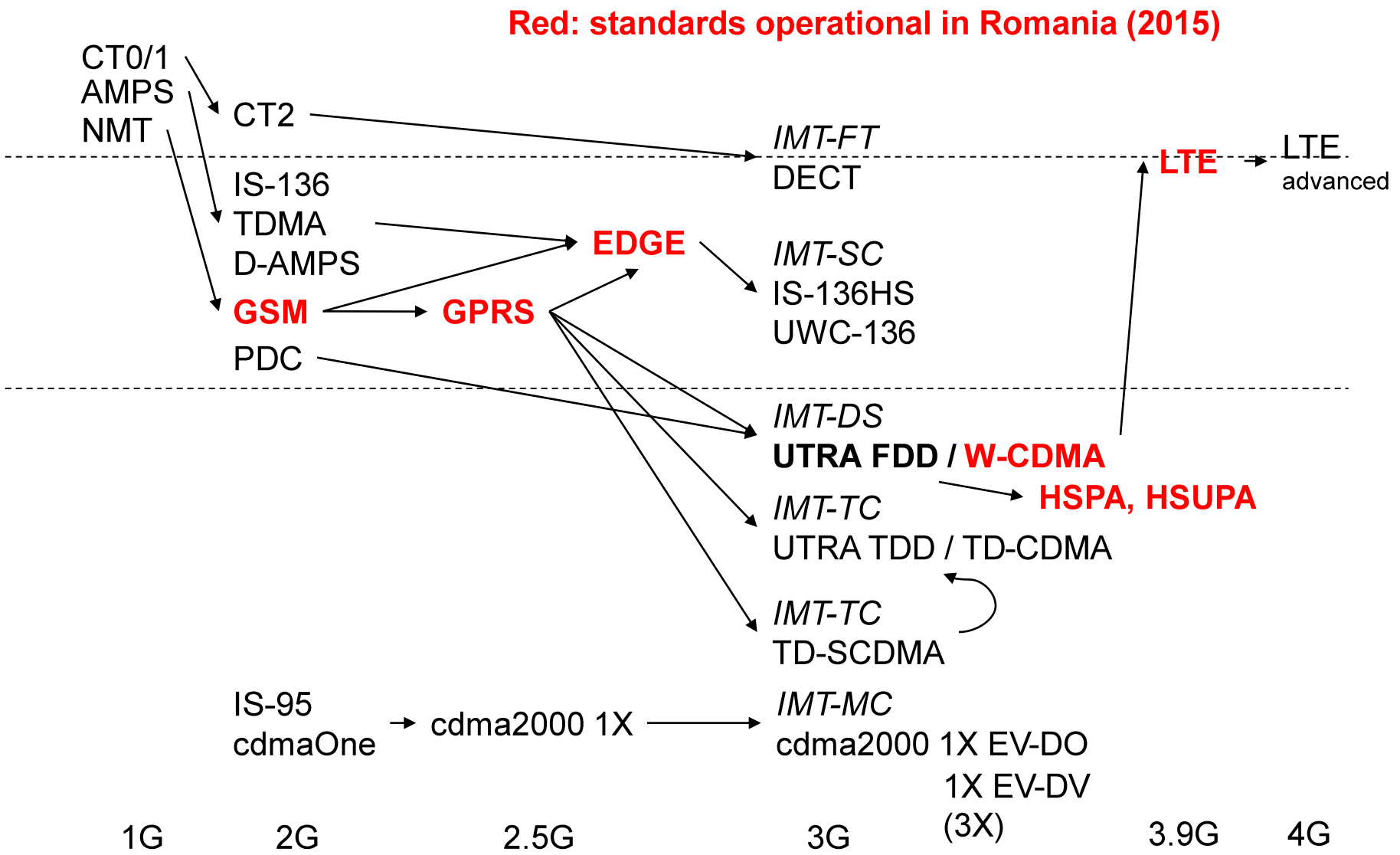
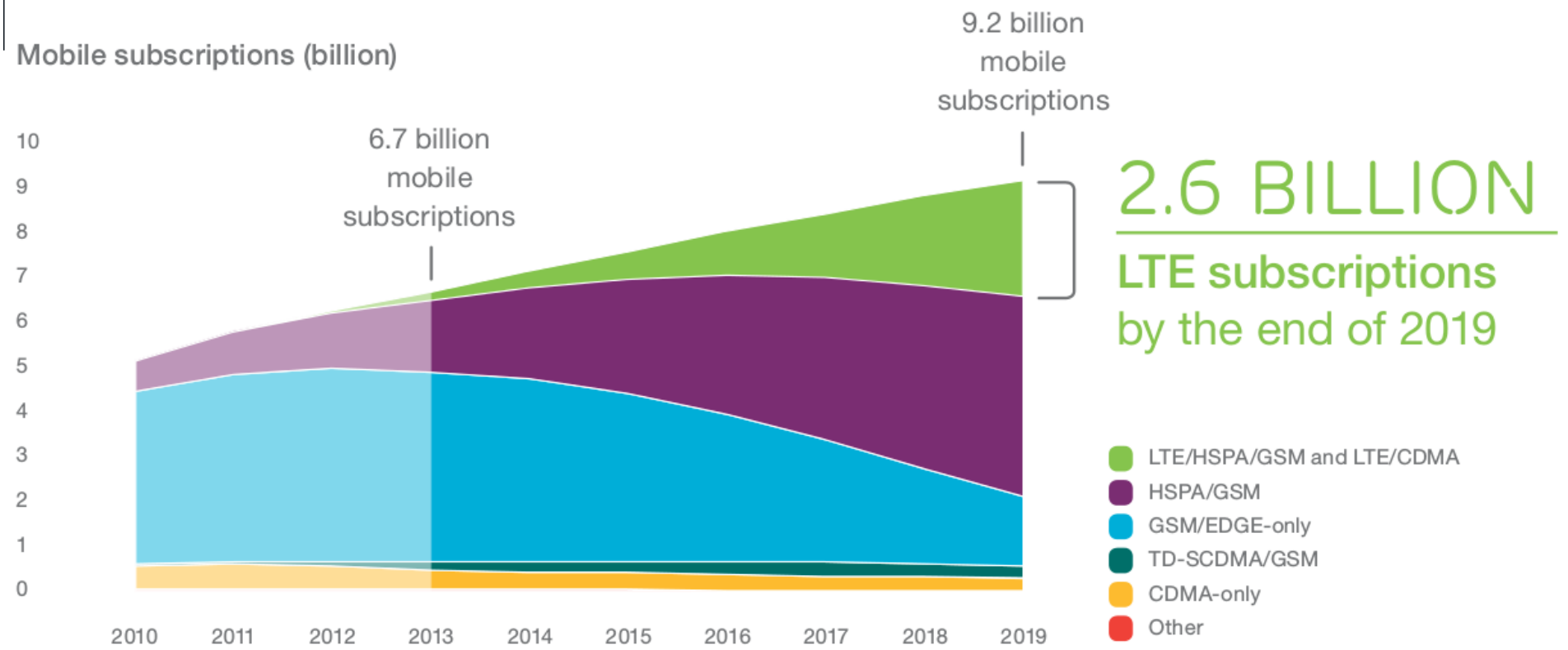
Sisteme de telecomunicații fără fir

- 2G: GSM, GPRS
- 3G: UMTS/HSPA
- 4G: LTE
- Piața din România

Mobile systems



ERICSSON MOBILITY REPORT, JUNE2014



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- Auto
- IT
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Traficul pe retelele 4G va creste de 16 ori in intervalul 2015 ¬ 2020 in Europa Centrala si de Est, arata un raport Cisco

de Vlad Barza **HotNews.ro**
Joi, 11 februarie 2016, 12:18 Economie | Telecom

La nivel mondial numarul de utilizatori ai dispozitivelor mobile va creste cu 700 de milioane, pana la 5,5 miliarde in 2020, 360 de milioane dintre ei urmand sa fie in regiunea central si est europeana. In aceasta zona, traficul pe retelele 4G va creste de 16 ori, iar clipurile video vor genera trei

How does it work?

- How can the system locate a user?
- Why don't all phones ring at the same time?
- What happens if two users talk simultaneously?
- Why don't I get the bill from my neighbor?
- how can an Australian use her phone in Berlin?

- Why can't I simply overhear the neighbor's communication?
- How is a call maintained when moving?
- What are the key components of the mobile phone network?

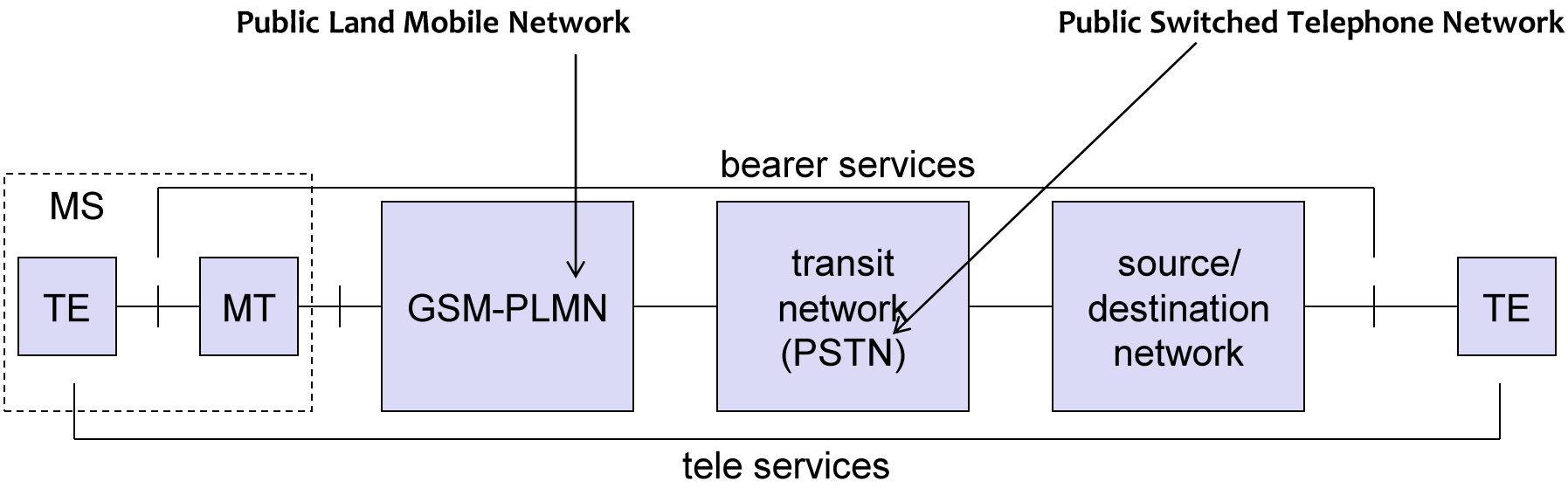
GSM Overview

- **GSM** = Global System for Mobile Communication
  - ETSI = European Telecommunications Standardisation Institute
  - simultaneous introduction of essential services three phases (1991, 1994, 1996)
    :-) seamless roaming within Europe possible

- **Communication**
  - mobile, wireless communication; support for voice and data services
- **Total mobility**
  - international access, chip-card enables use of access points of different providers
- **Worldwide connectivity**
  - one number, the network handles localization

GSM: Mobile Services

- GSM offers
  - voice connections (3.1KHz) – primary goal
    - Emergency number
    - Multinumber
  - data @ 9.6Kbps
  - SMS (short message service)



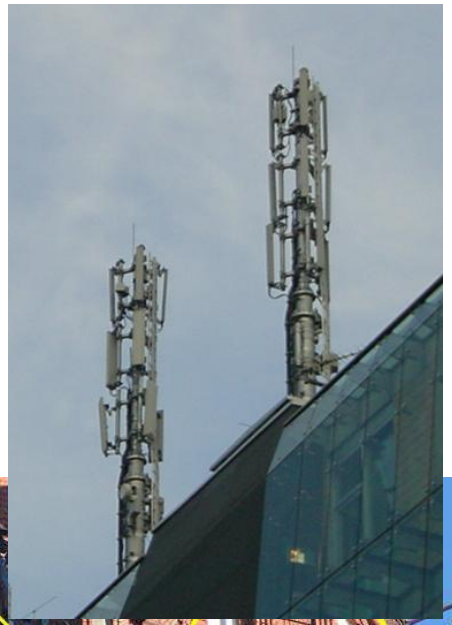
Architecture of the GSM system

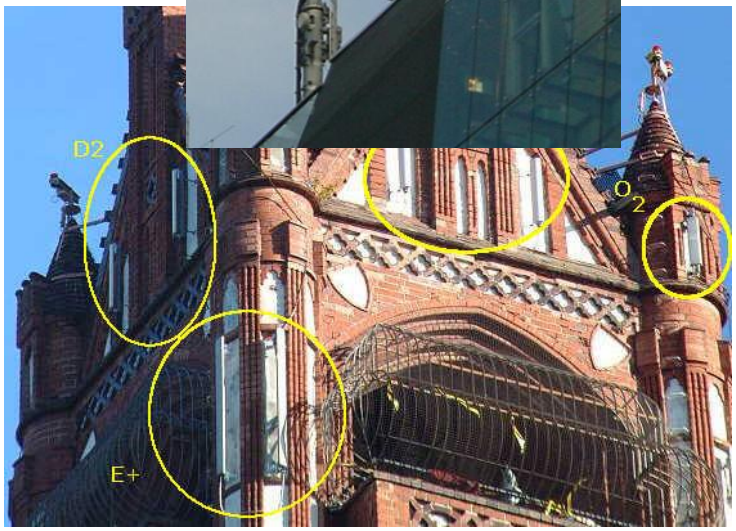
- GSM is a PLMN (Public Land Mobile Network)
  - several providers within each country
  - components
    - MS (mobile station)
    - BS (base station)
    - MSC (mobile switching center)
    - LR (location register)
  - subsystems
    - RSS (radio subsystem): covers all radio aspects
    - NSS (network and switching subsystem): call forwarding, handover, switching
    - OSS (operation subsystem): management of the network

Ingredients 1: Mobile Phones, PDAs

The visible but smallest part of the network!

Ingredients 2: Antennas

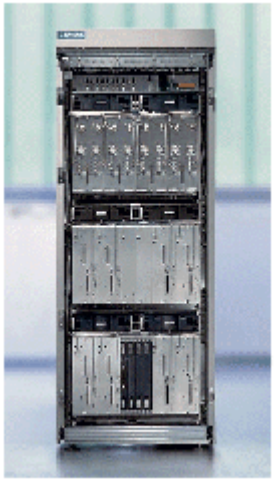




Still visible – cause many discussions…

Ingredients 3: Infrastructure 1

Base Stations



Cabling

Microwave links

Ingredients 3: Infrastructure 2

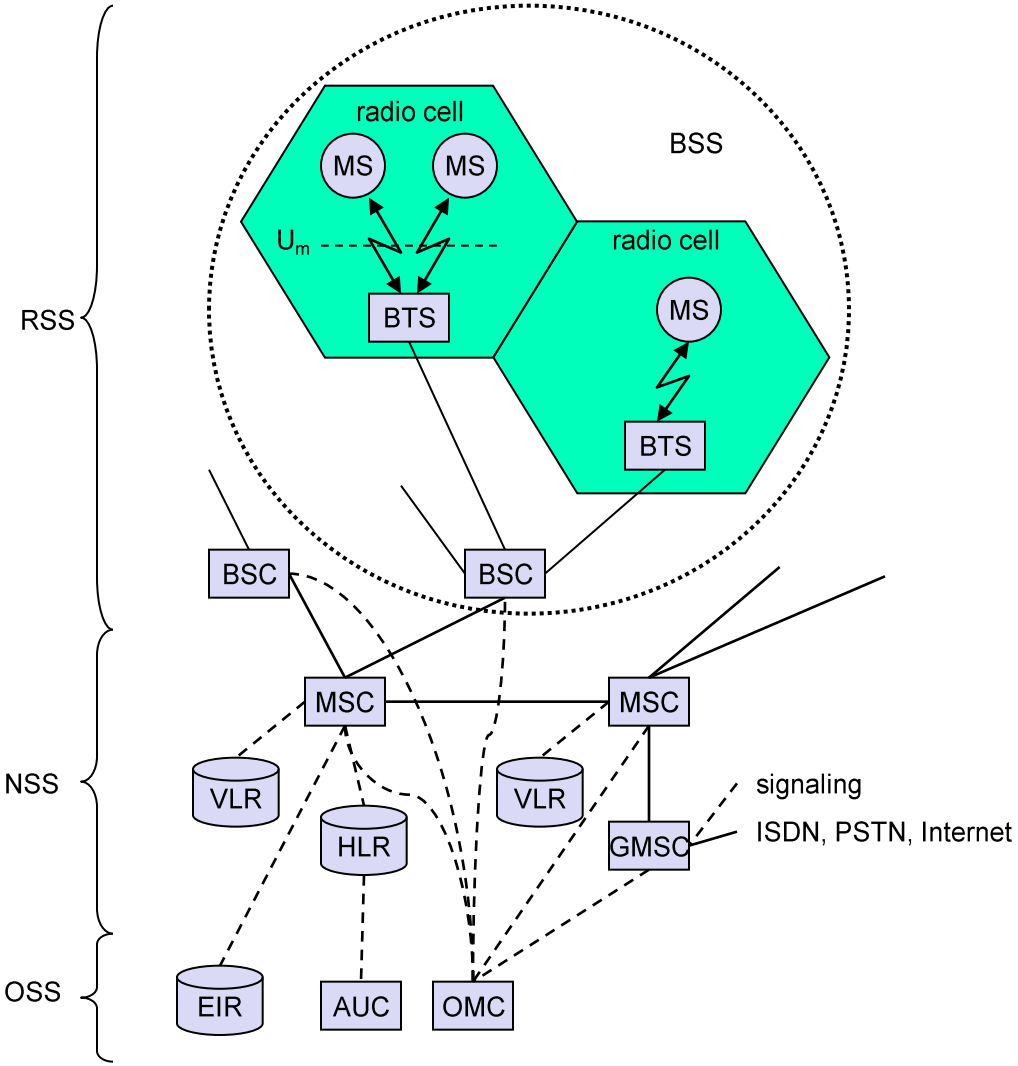
Switching units

Management databases

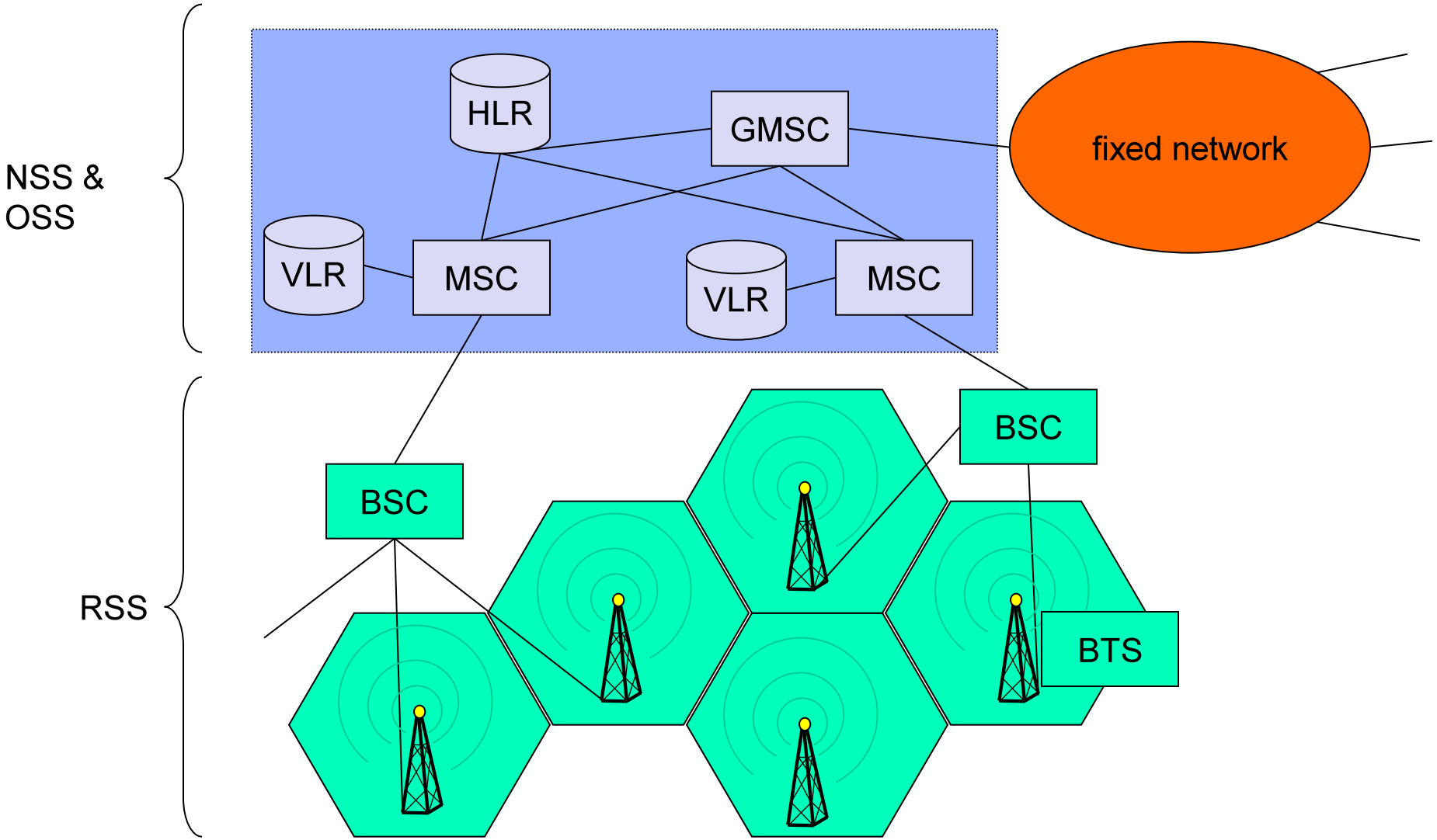
Not „visible“, but comprise the major part of the network (also costwise)

Monitoring

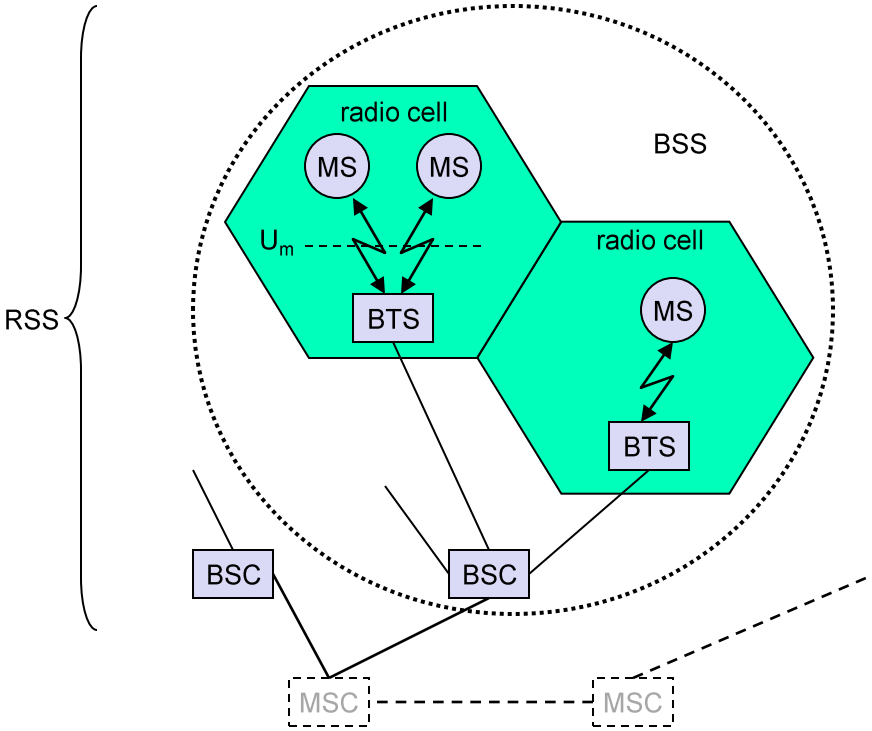
GSM: elements and interfaces



GSM: overview



radio subsystem



- **Components**
  - *MS* (Mobile Station)
  - *BSS* (Base Station Subsystem): consisting of
    - *BTS* (Base Transceiver Station): sender and receiver
    - *BSC* (Base Station Controller): controlling several transceivers

radio subsystem RSS

- Components:
  - Base Station Subsystem (BSS):
    - Base Transceiver Station (BTS): radio components including sender, receiver, antenna - if directed antennas are used one BTS can cover several cells
    - Base Station Controller (BSC): switching between BTSs, controlling BTSs, managing of network resources
    - BSS = BSC + sum(BTS) + interconnection
  - Mobile Stations (MS)

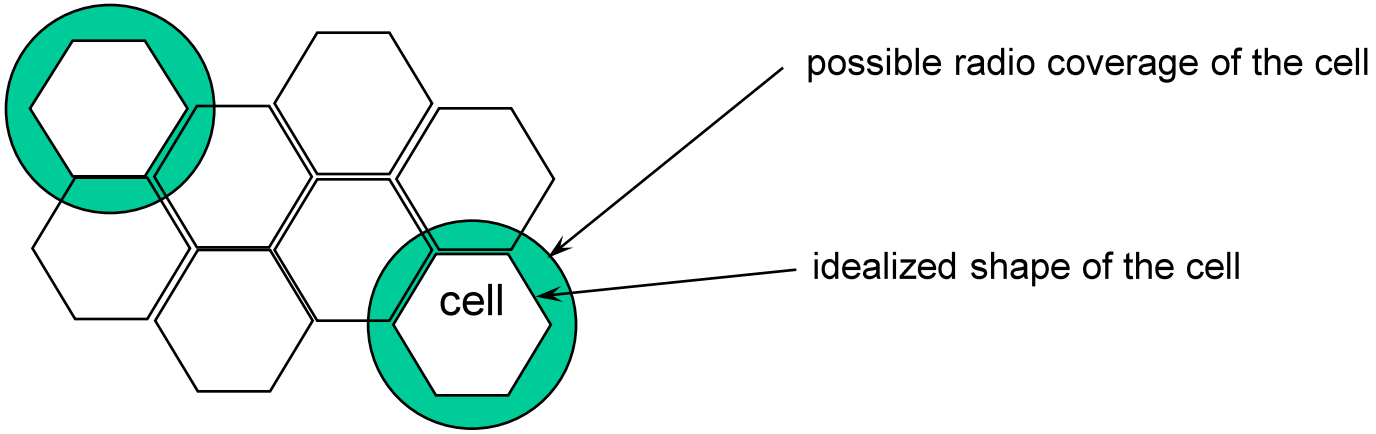
BTS and BSC

- **BTS comprises radio specific functions**
- **BSC is the switching center for radio channels**

Functions	BTS	BSC
Management of radio channels		X
Frequency hopping (FH)	X	X
Management of terrestrial channels		X
Mapping of terrestrial onto radio channels		X
Channel coding and decoding	X	
Rate adaptation	X	
Encryption and decryption	X	X
Paging	X	X
Uplink signal measurements	X	
Traffic measurement		X
Authentication		X
Location registry, location update		X
Handover management		X

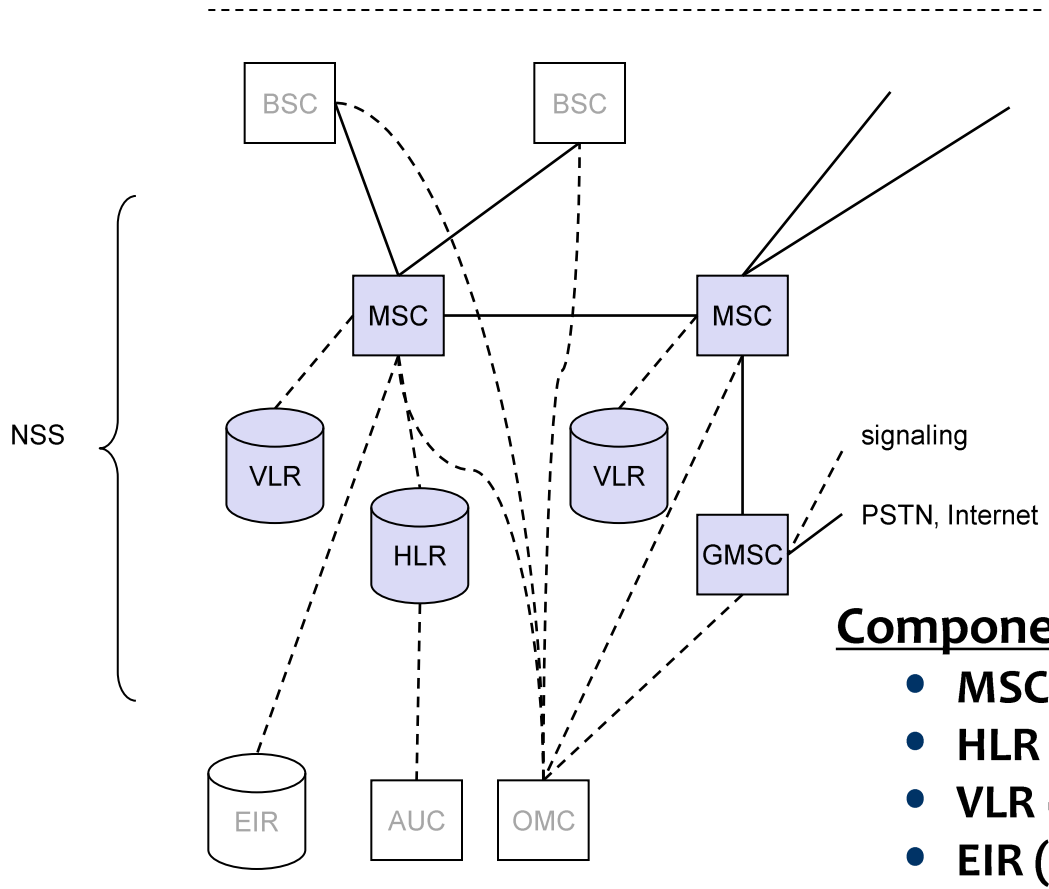
GSM: cellular network

segmentation of the area into cells



- use of several carrier frequencies
- not the same frequency in adjoining cells
- cell sizes: 100m .. 35 km (population density, geography, transceiver power)
- hexagonal shape is idealized (cells overlap, shapes depend on geography)
- handover/handoff: user moves from cell to neighboring cell

network and switching subsystem



Components

- MSC (Mobile Services Switching Center)
- HLR (Home Location Register)
- VLR (Visitor Location Register)
- EIR (Equipment Identity Register)
- GMSC(Gateway MSC)

Connect to other networks

- PSTN (Public Switched Telephone Network)

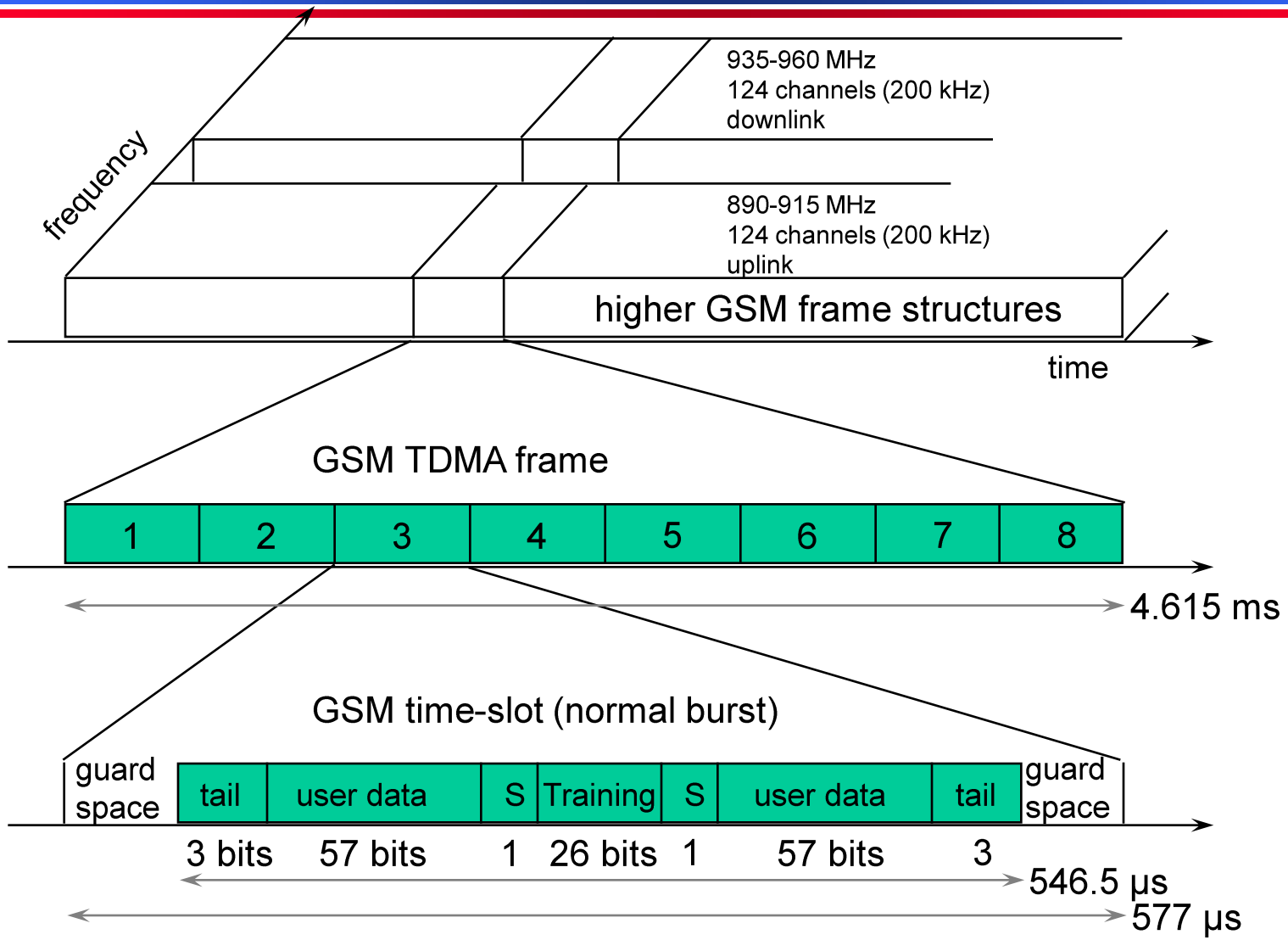
network and switching subsystem

- NSS is the central component of GSM
  - switching, mobility management, interconnection to other networks, system control
- Components
  - Mobile Services Switching Center (MSC)
    controls all connections via a separated network to/from a mobile terminal within the domain of the MSC - several BSC can belong to a MSC
  - Databases (important: scalability, high capacity, low delay)
    - Home Location Register (HLR)
      central master database containing user data, permanent and semi-permanent data of all subscribers assigned to the HLR (one provider can have several HLRs)
    - Visitor Location Register (VLR)
      local database for a subset of user data, including data about all user currently in the domain of the VLR

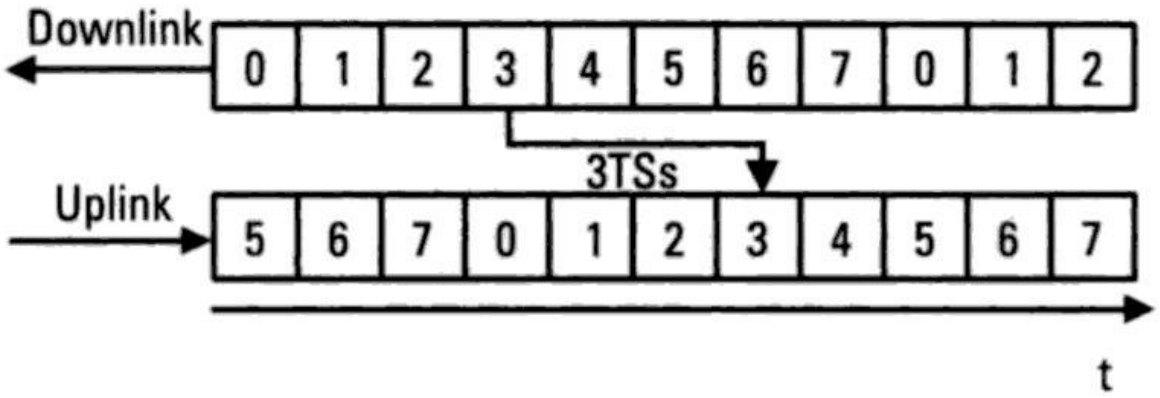
Mobile Services Switching Center

- The MSC (mobile services switching center) plays a central role in GSM
  - switching functions
  - additional functions for mobility support
  - management of network resources
  - interworking functions via Gateway MSC (GMSC)
  - integration of several databases
- Functions of a MSC
  - specific functions for paging and call forwarding
  - mobility specific signaling
  - location registration and forwarding of location information
  - provision of new services (fax, data calls)
  - support of short message service (SMS)
  - generation and forwarding of accounting and billing information

GSM – TDMA+FDMA



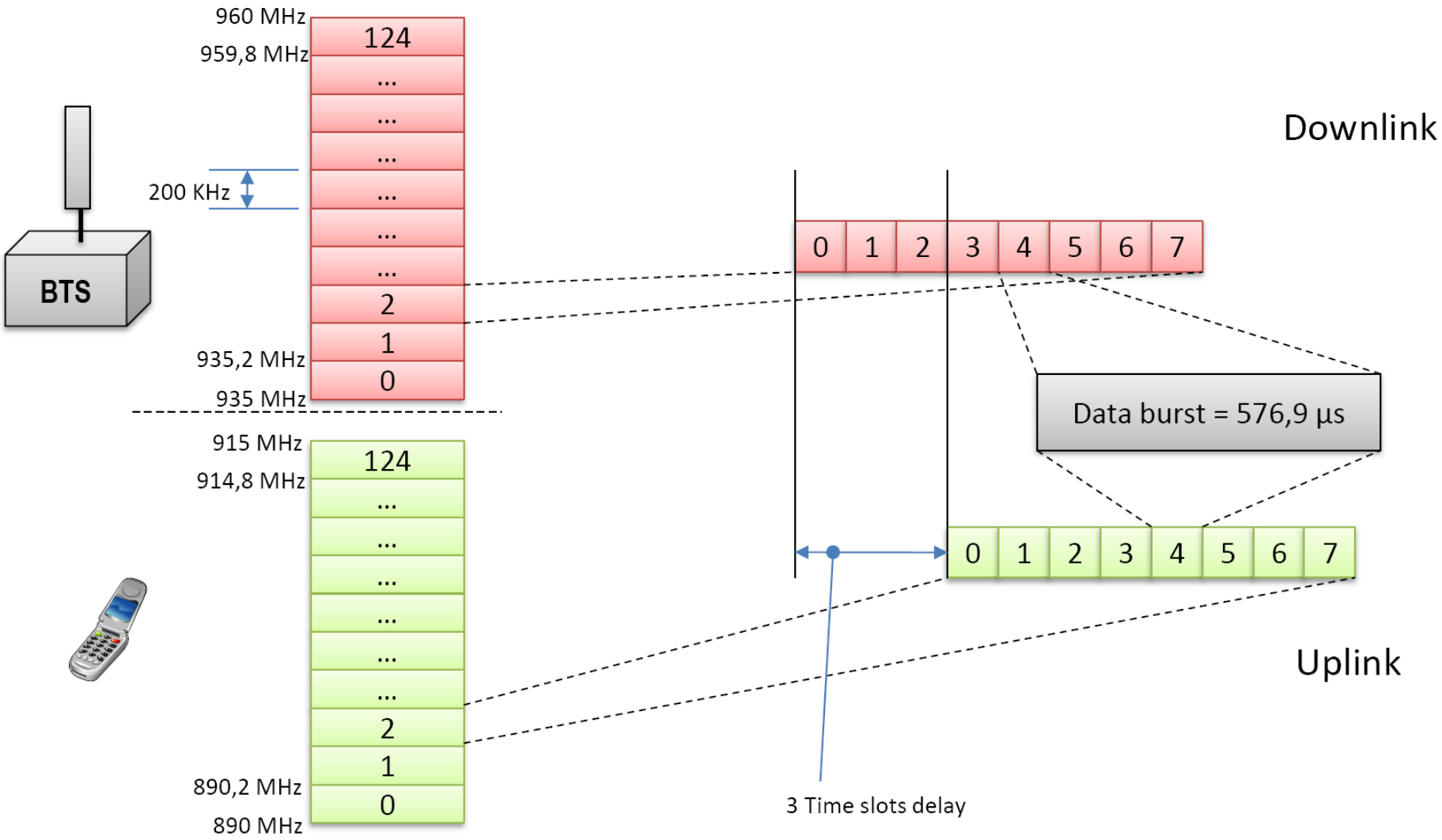
Total = 8*124 duplex channels



- MS uses the same slot on uplink and downlink
- The BS always sends 3 slots before the MS
- MS must wait 3 slots before sending
- Most MSs cannot send & receive simultaneously
  - Why? … half duplex hardware

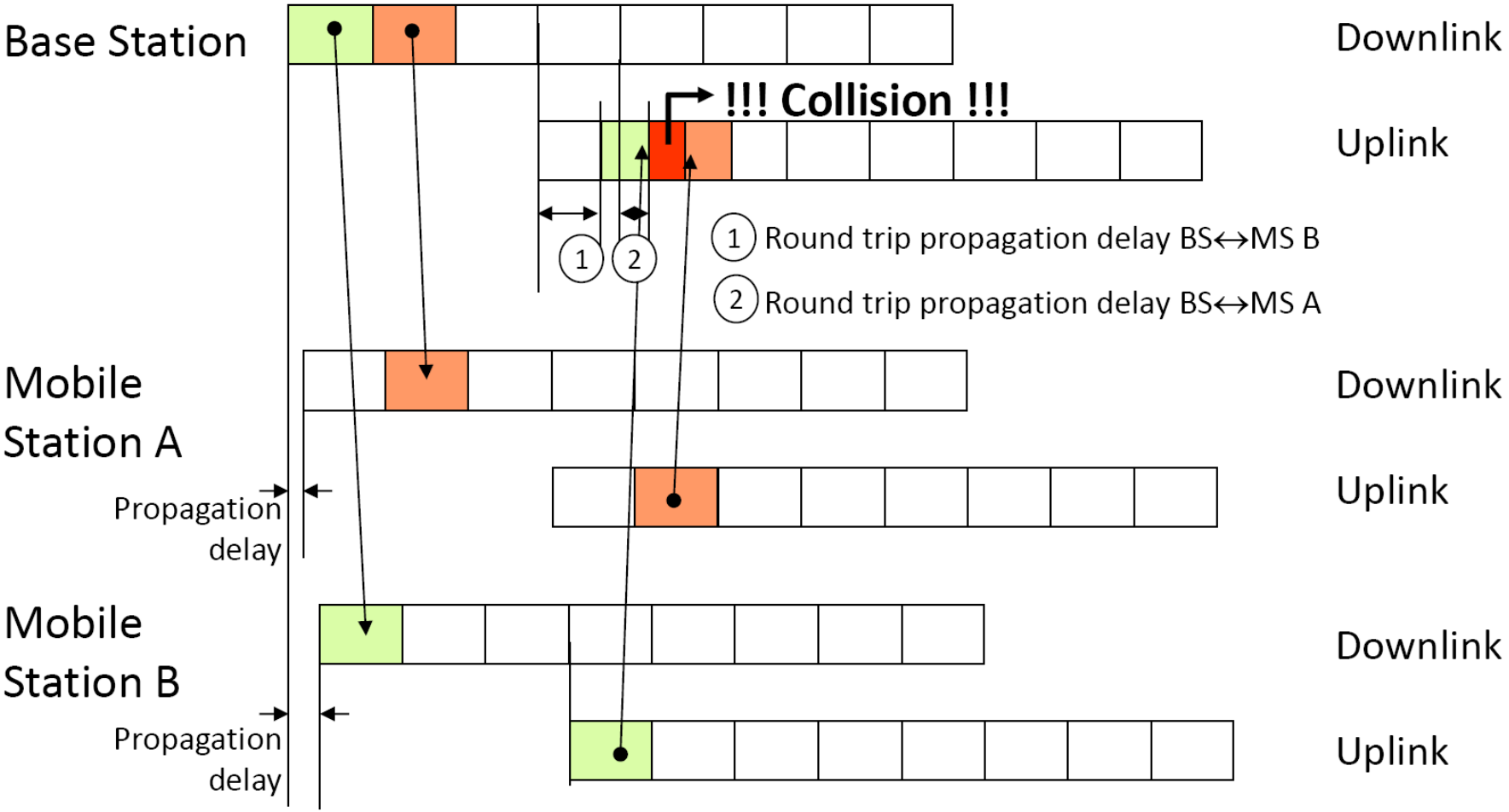
GSM – medium access issue

- Combination of TDMA and FDMA



GSM – impact of propagation delay

Problem: As the distance between a mobile and a base station usually varies, the signal propagation delays between them also vary → **adjacent channel interference**



GSM – guard intervals

- Guard times between time slots avoid co-channel interference caused by different propagation delays
- Example:
  - Distance between MS and BS: 35 km
  - Synchronization signal from BS arrives after

$$\frac{35 \cdot 10^3 \text{ m}}{3 \cdot 10^8 \text{ m/s}} = 117 \mu\text{s}$$

  - Necessary guard time: 234 µs

→ Problem: guard times decrease capacity

  - 234 µs guard time lowers capacity by 40 %!

→ Solution: **Adaptive frame spacing**

  - Guard time can be reduced down to 30 µs

GSM – logical channels

Total 8*124 = 992 channels:

- Traffic channels (voice, data 9.6Kbps)
- Broadcast control (BCCH)
- Random access channel (RACH)
- Paging channel (PGCH)
- SMS and USSD

BCCH

- Broadcast Control Channel (BCCH):
  - Location Area Identity (LAC)
  - List of neighboring cells
  - List of frequencies used in the cell
  - Cell identity
  - Power control indicator
  - Access control (emergency, call barring)

- The BCCH is transmitted at constant power at all times
- all MS may use it to measure its signal strength !

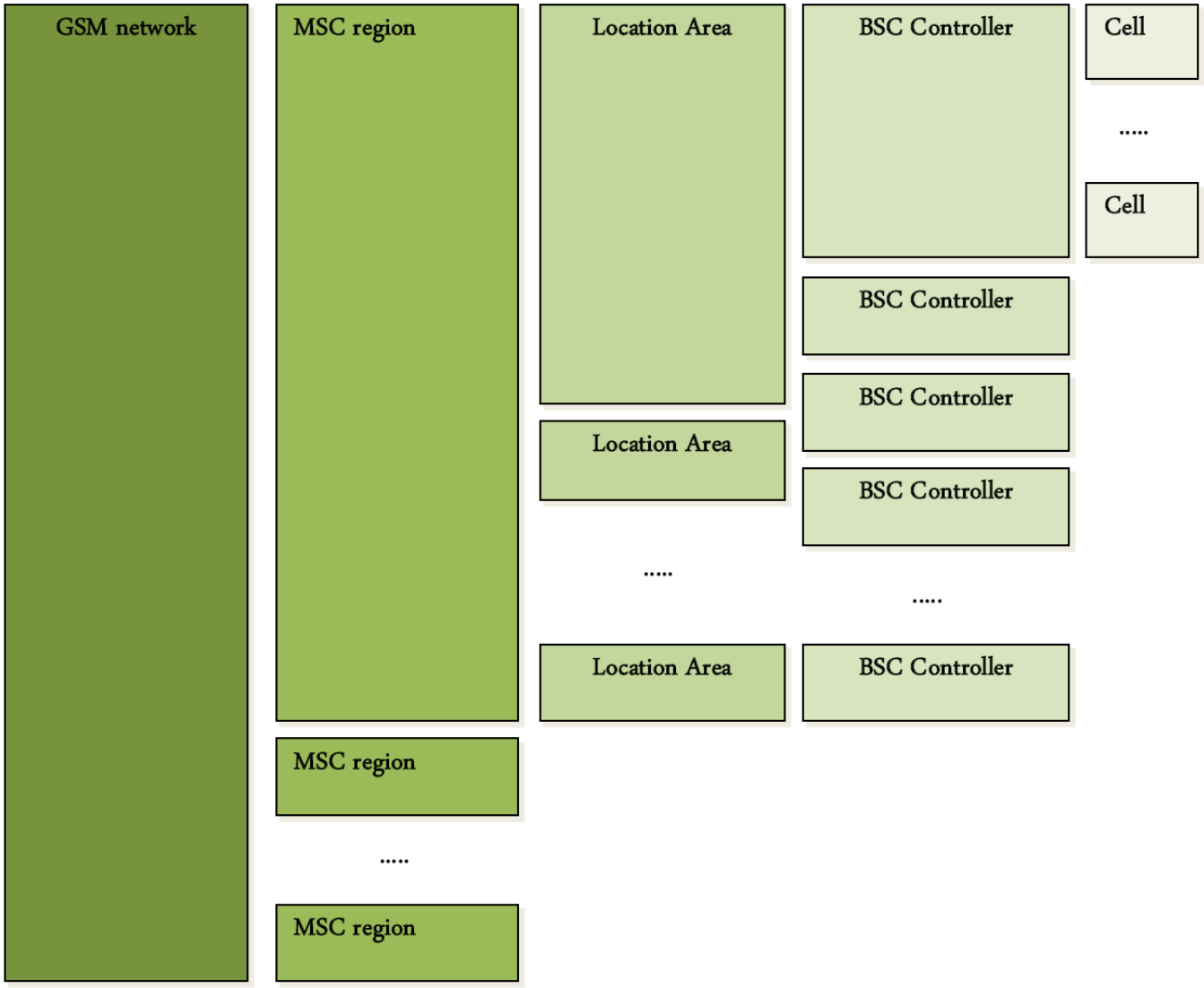
Common Control channels

- RACH (random access channel)
  - To gain access to the system
  - Uses slotted ALOHA :-)
- PCH (paging channel)
  - Where is a mobile? … in some ‘location area’
- ACGH (access grant control channel)
  - Mobile moves here to setup call, after RACH

- Active mobiles should monitor BCCH & CCCH frequently

Physical deployment

- GSM network consists of at least one administrative region, which is assigned to a *Mobile Switching Center* (MSC)
- Administrative domain is made up of at least one *location area* (LA)
- An LA consists of several cell groups
- A cell group is assigned to *Base Station Controller* (BSC)
- For each LA there exists at least one BSC, but cells of one BSC may belong to different LAs.



What is a location area (LA)?

- Mobile informed of incoming call by paging over the PCH
  - page every cell for each call?
    - waste of radio bandwidth
  - mobile send location updates at cell level.
    - Paging cut to 1 cell, but too many location updates

- cells are grouped into location areas
  - updates sent only when LA is changed
  - paging message sent to all cells in last known LA

- Bucharest location areas (cca 2010)
  - Vodafone: `32011, 32022, 32033`
  - Orange: `1010`
  - Cosmote: `7003, 7004`

Addresses and Identifiers

- **International Mobile Station Equipment Identity (IMEI)**
  - **It is similar to a serial number. It is allocated by equipment manufacturer, registered by network, and stored in EIR**

- **International Mobile Subscriber Identity (IMSI)**
  - **Used for identification, authentication**

MCC: Mobile Country Code
MNC: Mobile Network Code
MSIN: Mobile Subscriber Identification Number

When subscribing for service with a network, subscriber receives (IMSI) and stores it in the SIM (Subscriber Identity Module) card.
The HLR can be identified by a VLR/MSC from the IMSI.

Addresses and Identifiers

- **Mobile Subscriber ISDN (MSISDN)**
  - **The "real telephone number": associated with SIM**
  - **SIM can have several MSISDN numbers for voice,fax**
  - **Keep MSISDN whenever**
    - **change phone (IMEI)**
    - **change SIM (IMSI)**
  - **Portability across operators?**

NDC: National Destination Code (operator)
SN: Subscriber Number(identifies HLR)
CC: Country Code

Addresses and Identifiers

- **Location Area ID (LAI)**
  - **LAI is broadcast regularly by Base Station on BCCH**
  - **Each cell is identified uniquely as belonging to an LA by its LAI**

MCC: Mobile Country Code
MNC: Mobile Network Code
LAC: Location Area Code

Physical to logical maping

- CI (cell identity) = XXYYZ
  - XX: BSC number
  - YY: BTS number within the BSC
  - Z: Cell number within the BTS
  - Z: 0 =omni site; 1-8 = sectorial

- CGI (cell global identification)

  MCC-MNC-LAC-CI

- MCC=AAA: mobile country code
- MNC=BB: mobile network code
- LAC=ccCCC: location area code
- CI: cell id

Example

CGI = 226-01-32022-45913

- 226=MCC of Romania
- 01=MNC of Vodafone
- 32022=LAC
- 45913=CI
- This is cell of the BTS-91 in the BSC-45, sector 3

MMC, MNC în România

MCC	MNC	Brand	Operator	Status	Bands (MHz)	References and notes
226	01	Vodafone	Vodafone România	Operational	GSM 900/1800 UMTS 900/2100 LTE 1800	Formerly branded as Connex
226	02	Romtelecom	Romtelecom	Operational	CDMA 420	
226	03	Cosmote	Cosmote România	Operational	GSM 900/1800 LTE 1800	Formerly branded as Cosmorom
226	04	Cosmote/Zapp	Cosmote România	Not operational	CDMA 450	Licence expired on 24 March 2013, and network was shut down
226	05	Digi.Mobil	RCS&RDS	Operational	UMTS 2100	
226	06	Cosmote/Zapp	Cosmote România	Operational	UMTS 2100	Branded as Cosmote for data/voice and Zapp for data only
226	10	Orange	Orange România	Operational	GSM 900/1800 UMTS 900/2100 LTE 1800	Formerly branded as Dialog

Homework

- Dial: *#*#4636#*#*
- Android apps
  - G-NetTrack Lite, Netmonitor, G-Mon
  - Provide IMSI, IMEI, LAI (MCC, MNC, LAC), CellID, BSC/RNC, neighbor list, signal strength

- CELL Tower location

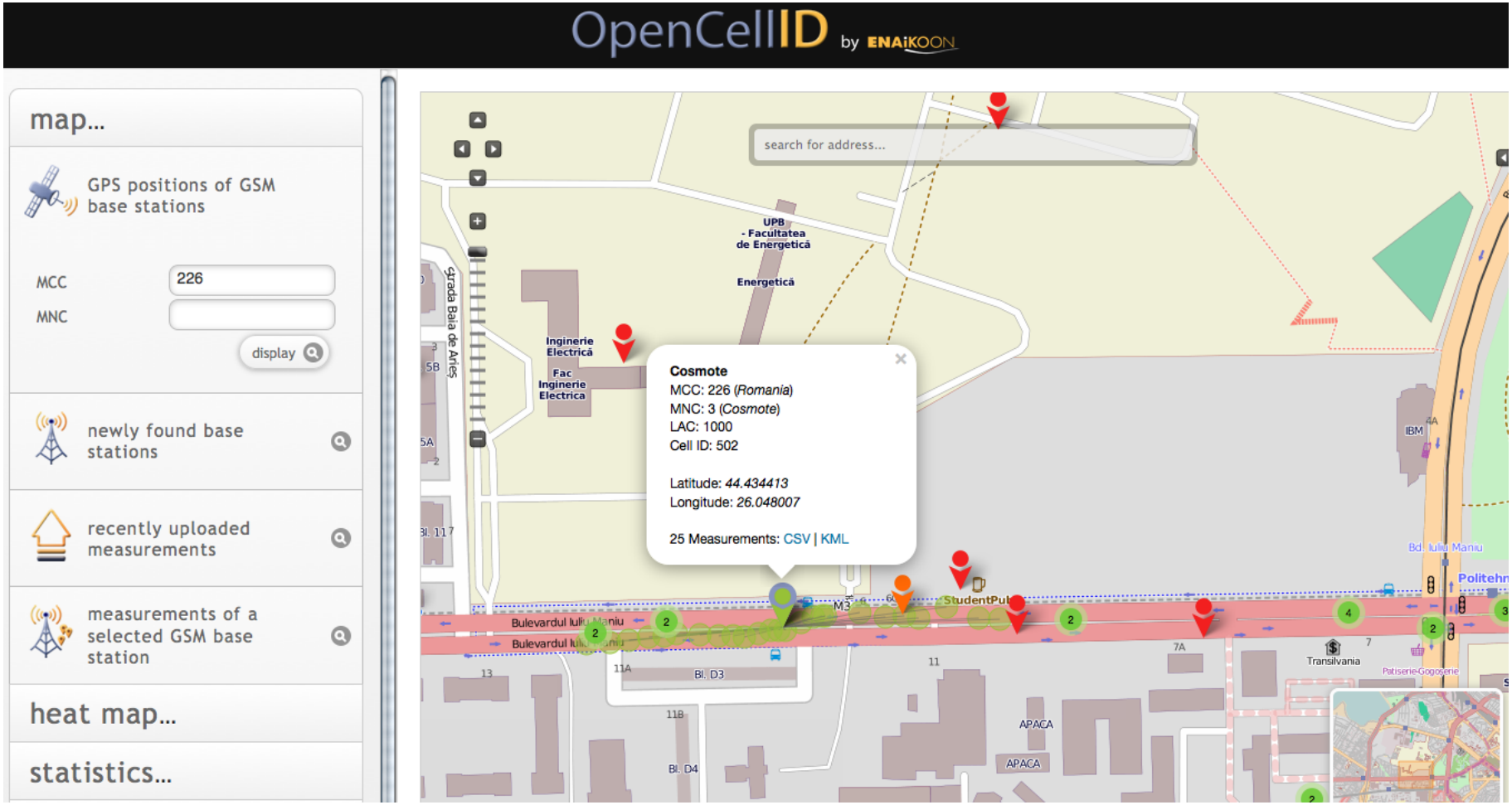
http://www.minigps.net/cellsearch.html

Mozilla Location Service

Open Cell ID

Google, Combain, Unwired - $$$

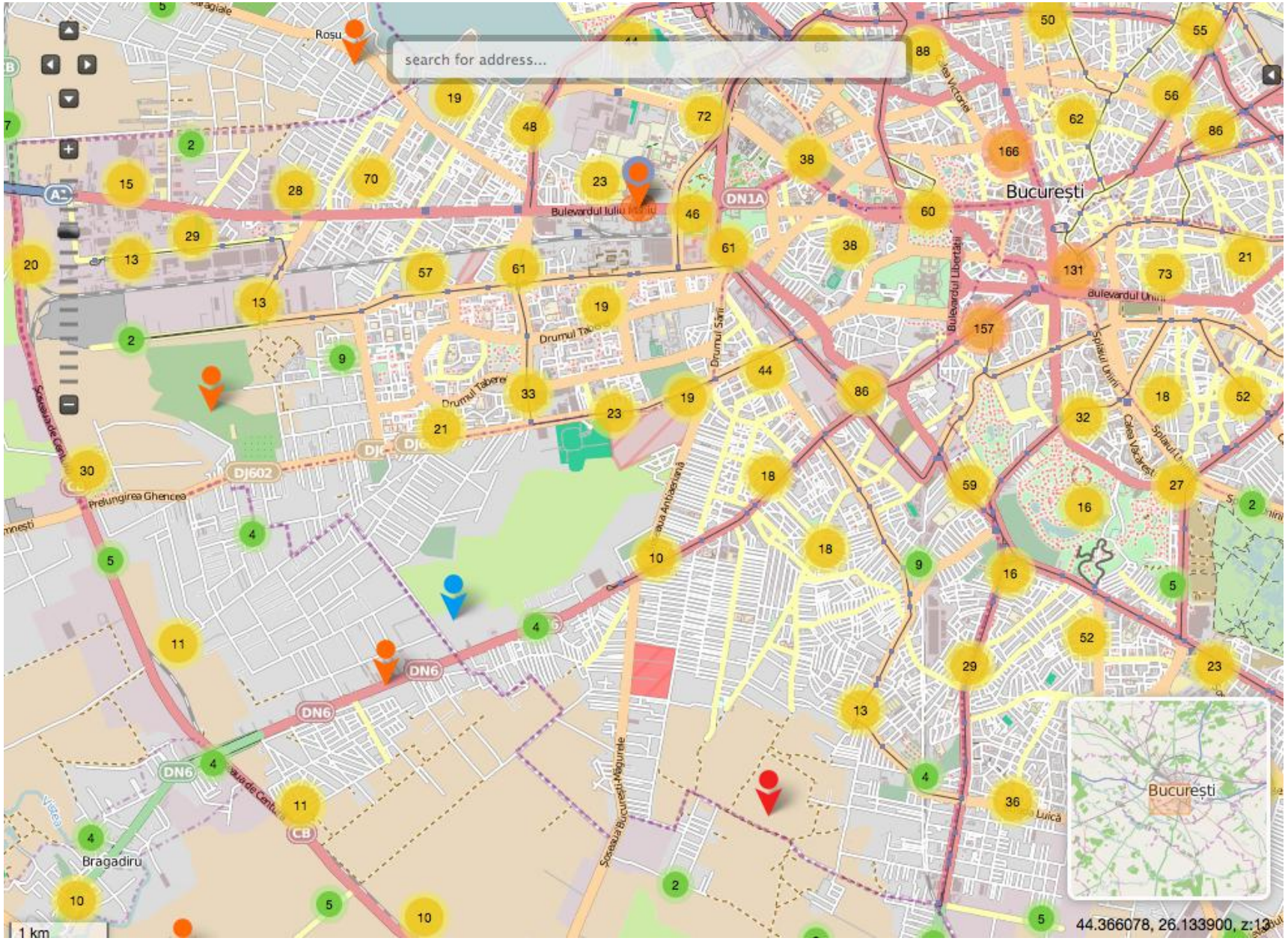
Open location DB (crowdourced, not complete)



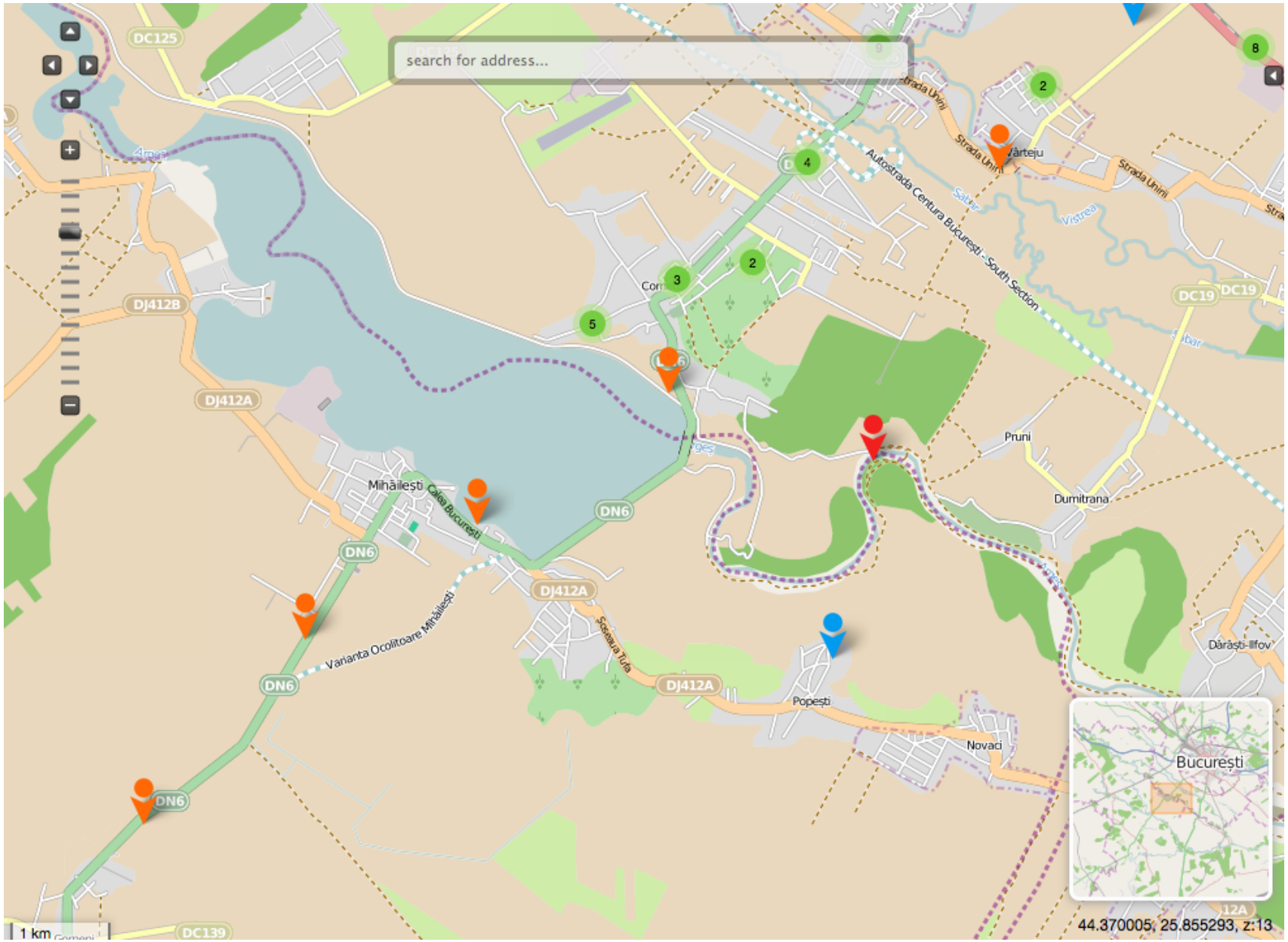
Warning:

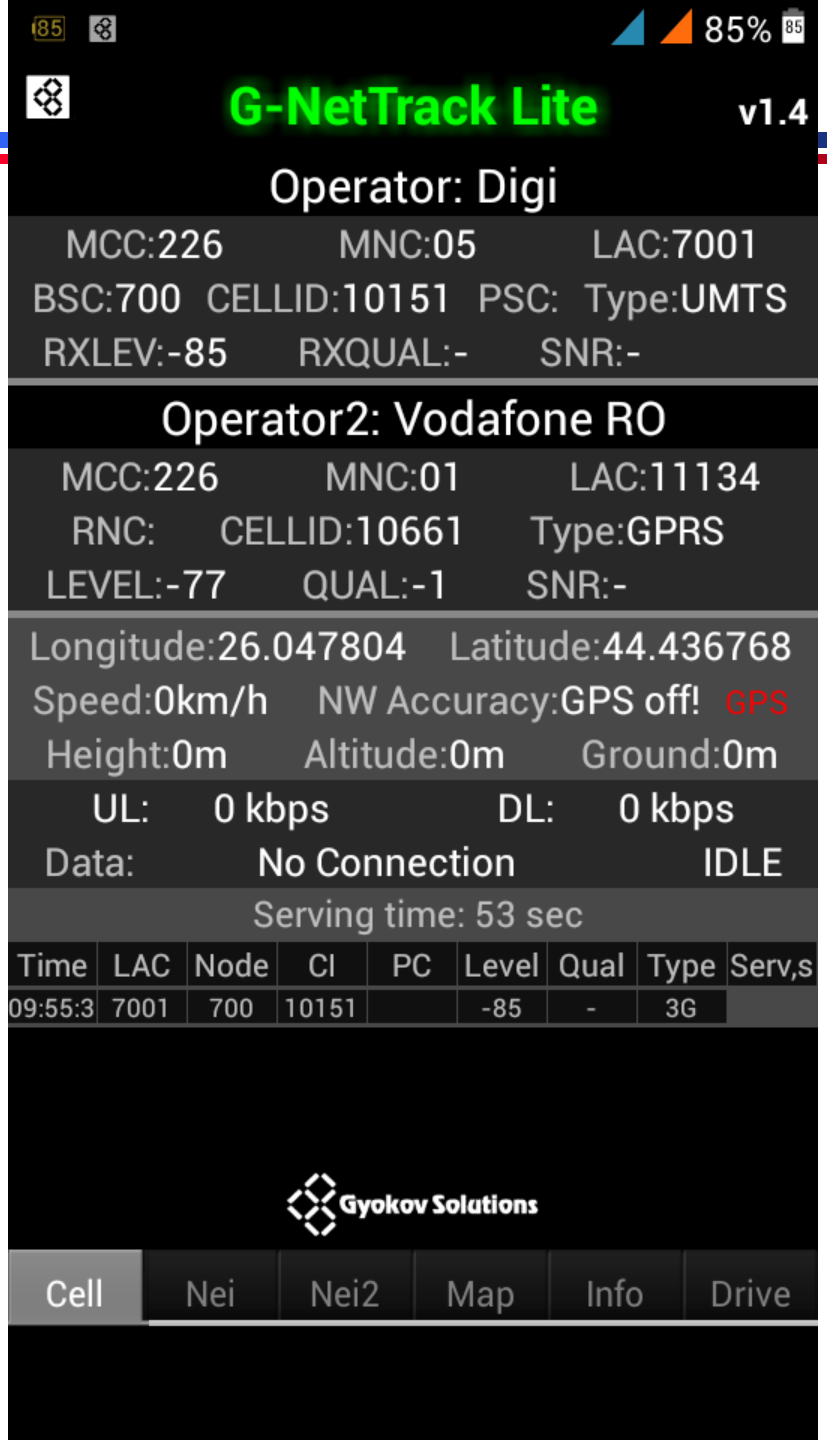
- database is not complete
- locations are approximate

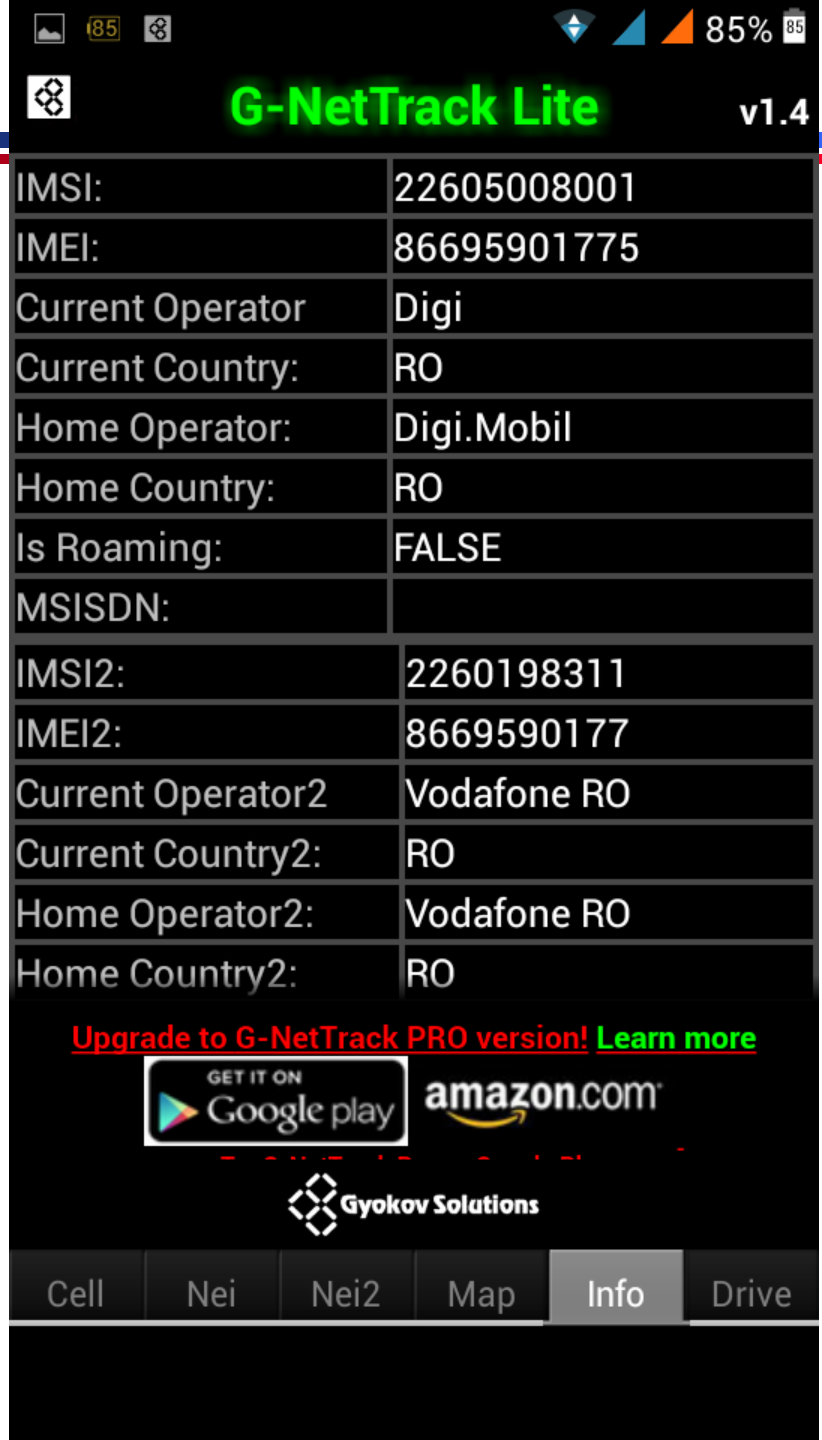
Urban density (crowdourced, not complete)



Rural density (crowdourced, not complete)




85%
G-NetTrack Lite
v1.4
Operator: Digi
MCC:226 MNC:05 LAC:7001
BSC:700 CELLID:10151 PSC: Type:UMTS
RXLEV:-85 RXQUAL:- SNR:-
Operator2: Vodafone RO
MCC:226 MNC:01 LAC:11134
RNC: CELLID:10661 Type:GPRS
LEVEL:-77 QUAL:-1 SNR:-
Longitude:26.047804 Latitude:44.436768
Speed:0km/h NW Accuracy:GPS off! GPS
Height:0m Altitude:0m Ground:0m
UL: 0 kbps DL: 0 kbps
Data: No Connection IDLE
Serving time: 53 sec
Time LAC Node CI PC Level Qual Type Serv,s
09:55:3 7001 700 10151 -85 - 3G
Gyokov Solutions
Cell Nei Nei2 Map Info Drive


85%
G-NetTrack Lite
v1.4
IMSI: 22605008001
IMEI: 86695901775
Current Operator Digi
Current Country: RO
Home Operator: Digi.Mobil
Home Country: RO
Is Roaming: FALSE
MSISDN:
IMSI2: 2260198311
IMEI2: 8669590177
Current Operator2 Vodafone RO
Current Country2: RO
Home Operator2: Vodafone RO
Home Country2: RO
Upgrade to G-NetTrack PRO version! Learn more
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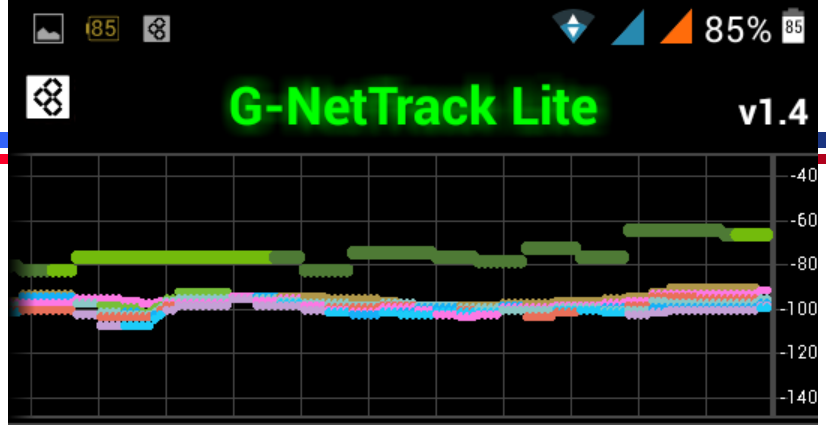
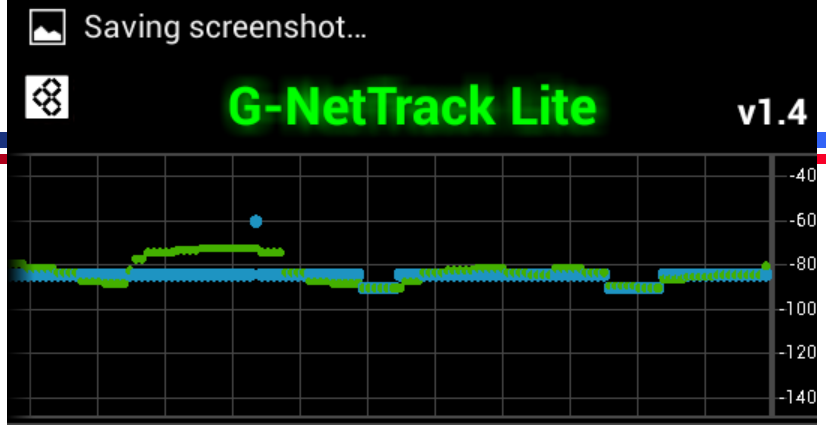


Type	LAC	CELLID/PC	RxLev,dBm
2G	11134	10662	-67

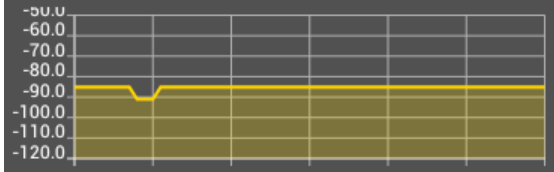
Type	LAC	NCELLID/PC	RxLev,dBm
2G	11134	10663	-92
2G	11134	45913	-92
2G	11134	45911	-96
2G	11134	10665	-98
2G	11134	45912	-99
2G	11134	10667	-100



Type	LAC	CELLID/PC	RxLev,dBm
3G	7001	700-10151	-85

Type	LAC	NCELLID/PC	RxLev,dBm
3G		99	-81

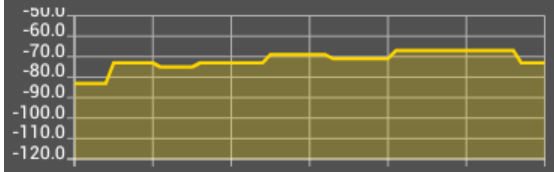
Operator: **226 05 (Digi)**
Type: **UMTS**
LAC: **7001** CID: **10151** RNC: **700**
Signal: -85 (dBm)



Bucharest, Bucharest, Sector 6

99 -57 (dBm)

Operator: **226 01 (Vodafone RO)**
Type: **GPRS**
LAC: **11134** CID: **10661**
Signal: -73 (dBm)

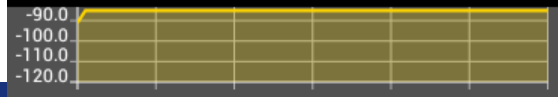


Bucharest, Bucharest, Strada Fabricii 47

11134 10661 -69 (dBm)
Bucharest, Bucharest, Strada Fabricii 47

11134 45913 -77 (dBm)
Bucharest, Bucharest, Bulevardul Iuliu Maniu 7

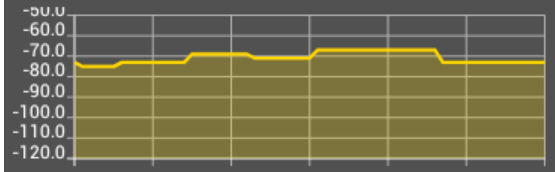
11134 10663 -77 (dBm)
Bucharest, Bucharest, Strada Arinii Dornei 16



Bucharest, Bucharest, Sector 6

99 -53 (dBm)

Operator: **226 01 (Vodafone RO)**
Type: **GPRS**
LAC: **11134** CID: **10661**
Signal: -73 (dBm)



Bucharest, Bucharest, Strada Fabricii 47

11134 45913 -81 (dBm)
Bucharest, Bucharest, Bulevardul Iuliu Maniu 7

11134 10662 -83 (dBm)
Bucharest, Bucharest, Bulevardul Iuliu Maniu 11A

11134 10663 -87 (dBm)
Bucharest, Bucharest, Strada Arinii Dornei 16

11134 45911 -87 (dBm)
Bucharest, Bucharest, Bulevardul General Vasile Milea 5

11134 45912 -89 (dBm)
Bucharest, Bucharest, Bulevardul Iuliu Maniu 3

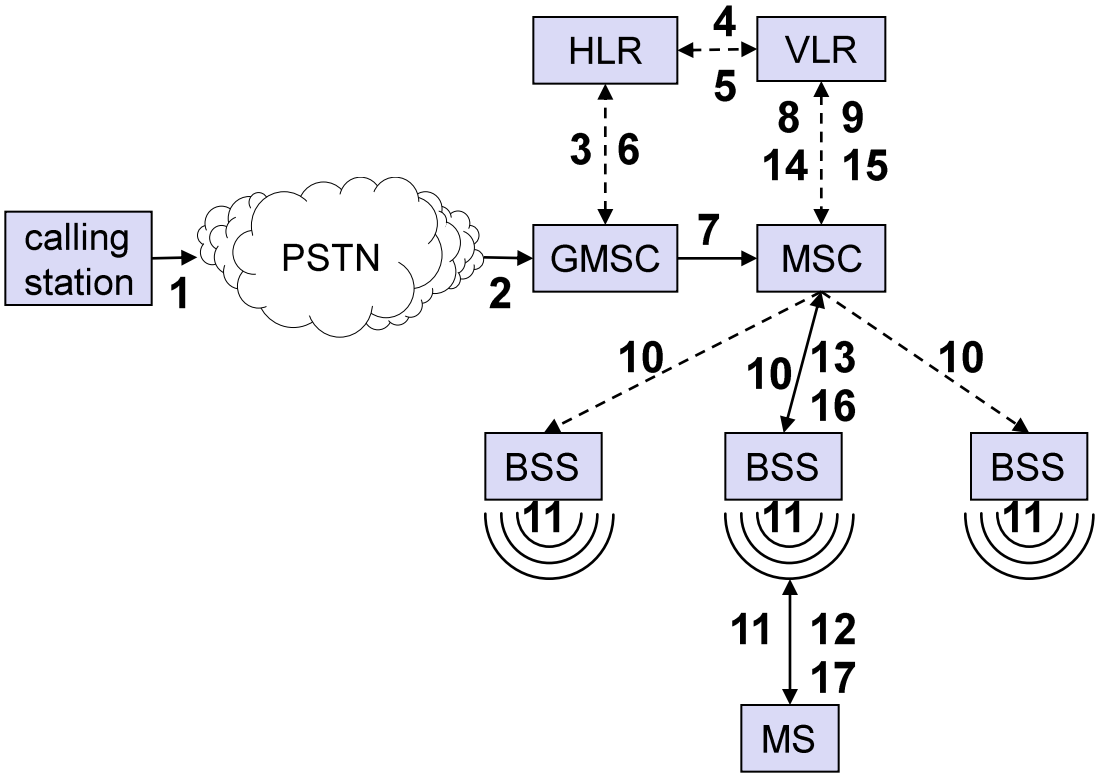
Location management

- Set of procedures to:
  - track a mobile user: HLR <-> VLR
  - find the mobile user to deliver its calls: VLR -> LA

- Roaming: temporary versions of IMSI, MSISDN

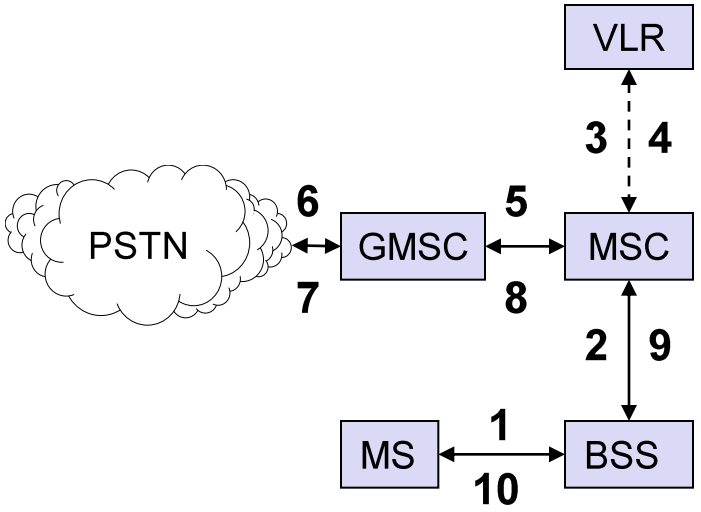
Mobile Terminated Call

- 1: calling a GSM subscriber
- 2: forwarding call to GMSC
- 3: signal call setup to HLR
- 4, 5: request MSRN from VLR
- 6: forward responsible MSC to GMSC
- 7: forward call to
- current MSC
- 8, 9: get current status of MS
- 10, 11: paging of MS
- 12, 13: MS answers
- 14, 15: security checks
- 16, 17: set up connection

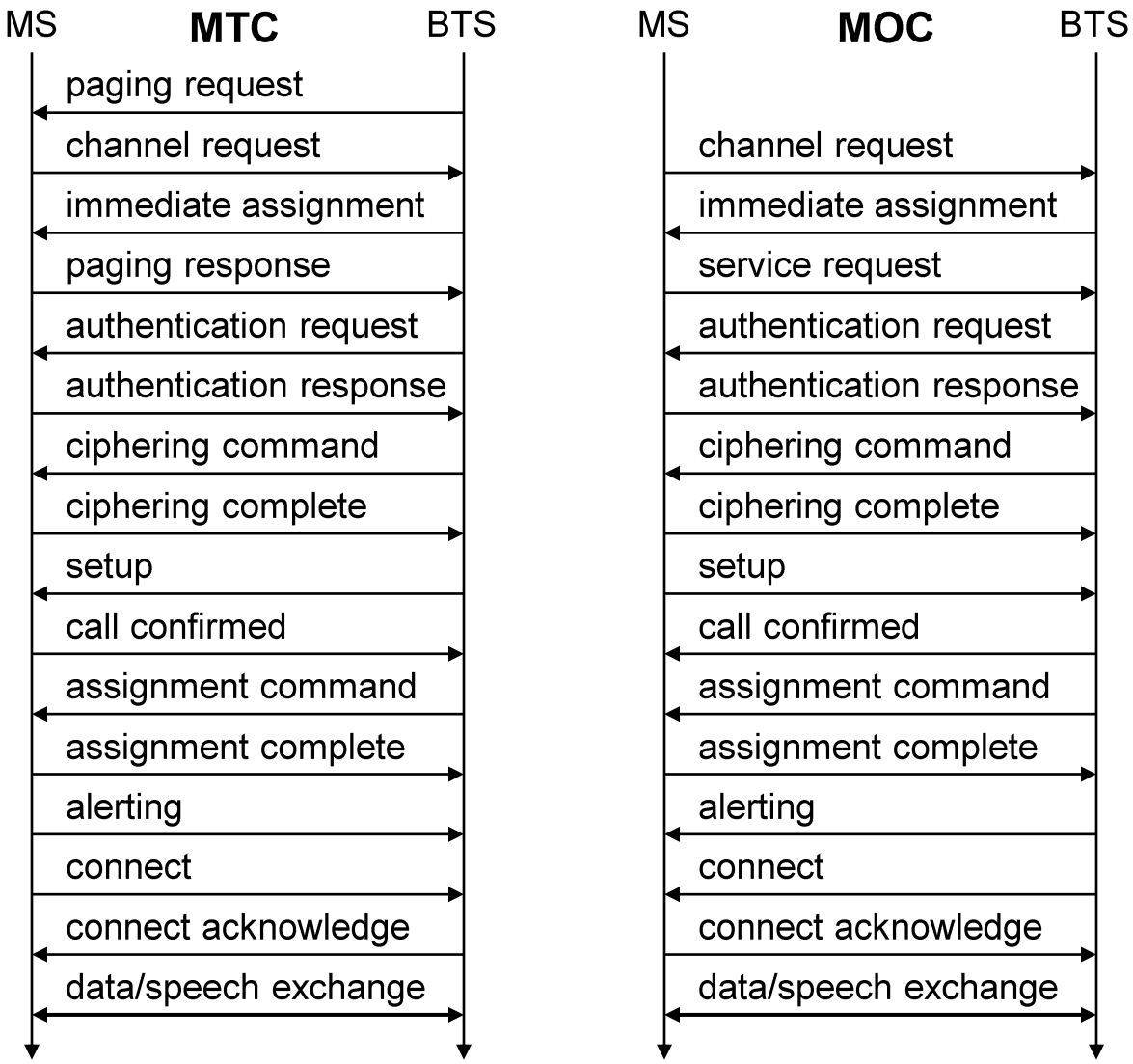


Mobile Originated Call

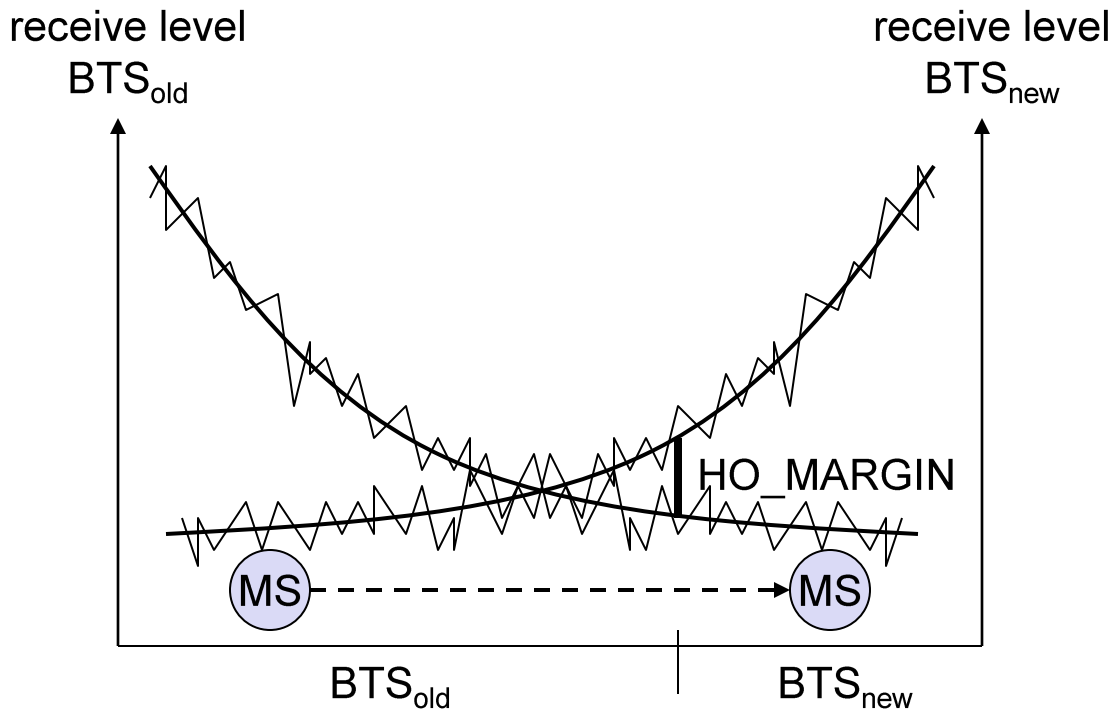
- 1, 2: connection request
- 3, 4: security check
- 5-8: check resources (free circuit)
- 9-10: set up call



Mobile Terminated/Originated Call



Handover decision

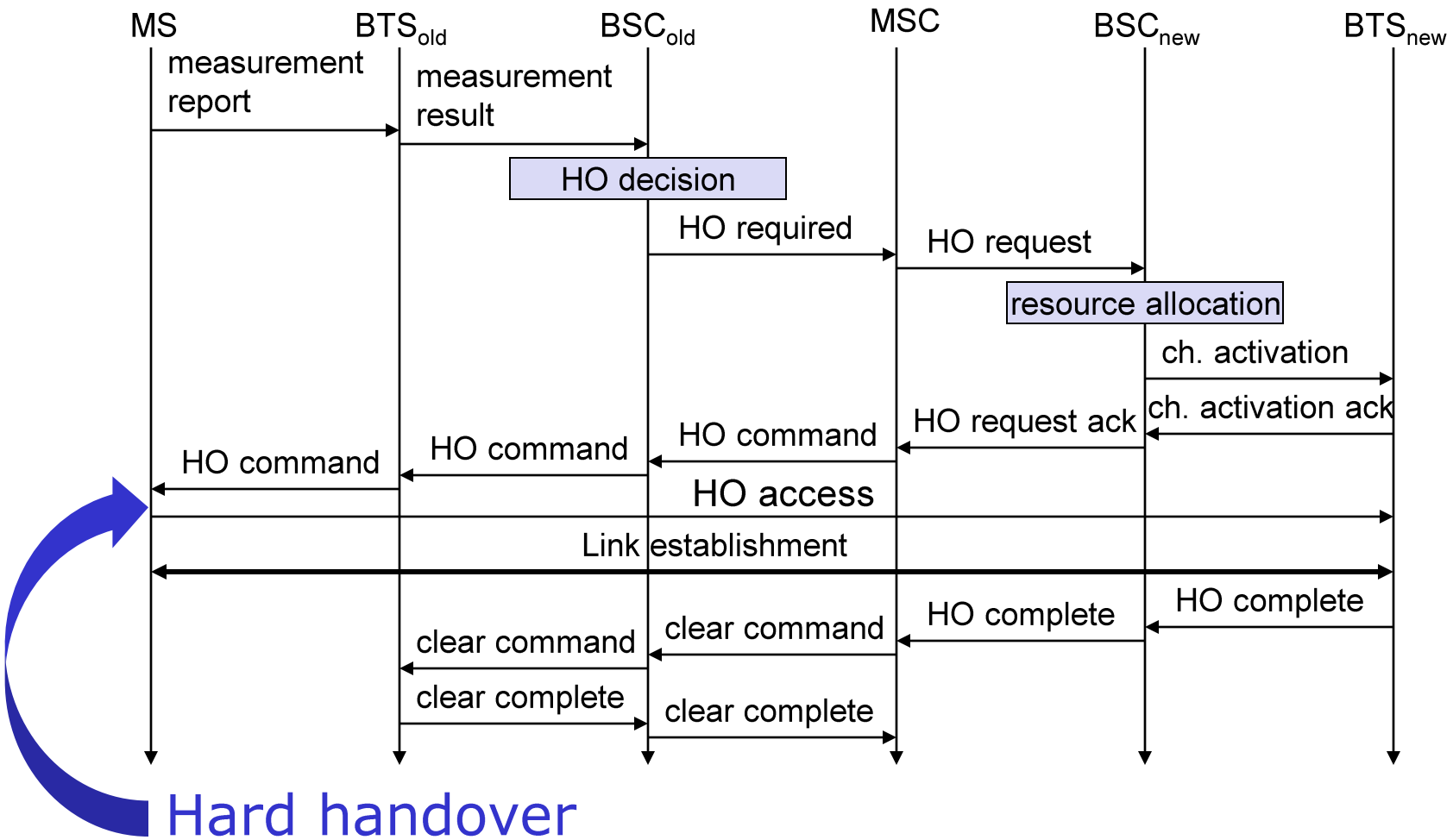


Mobile assisted handover

- What does the mobile do during the 6 free slots?
  - scans other channels for neighboring BTSs
  - reports link qualities of BCCHs, every second

- Final handover decision taken by the system (BSC, MSC)
  - which BTS_{new}
  - synchronization between BTS_{old} and BTS_{new}
  - adjust guard space for new distance
  - 60-200ms (audible)
  - update LA

Handover procedure

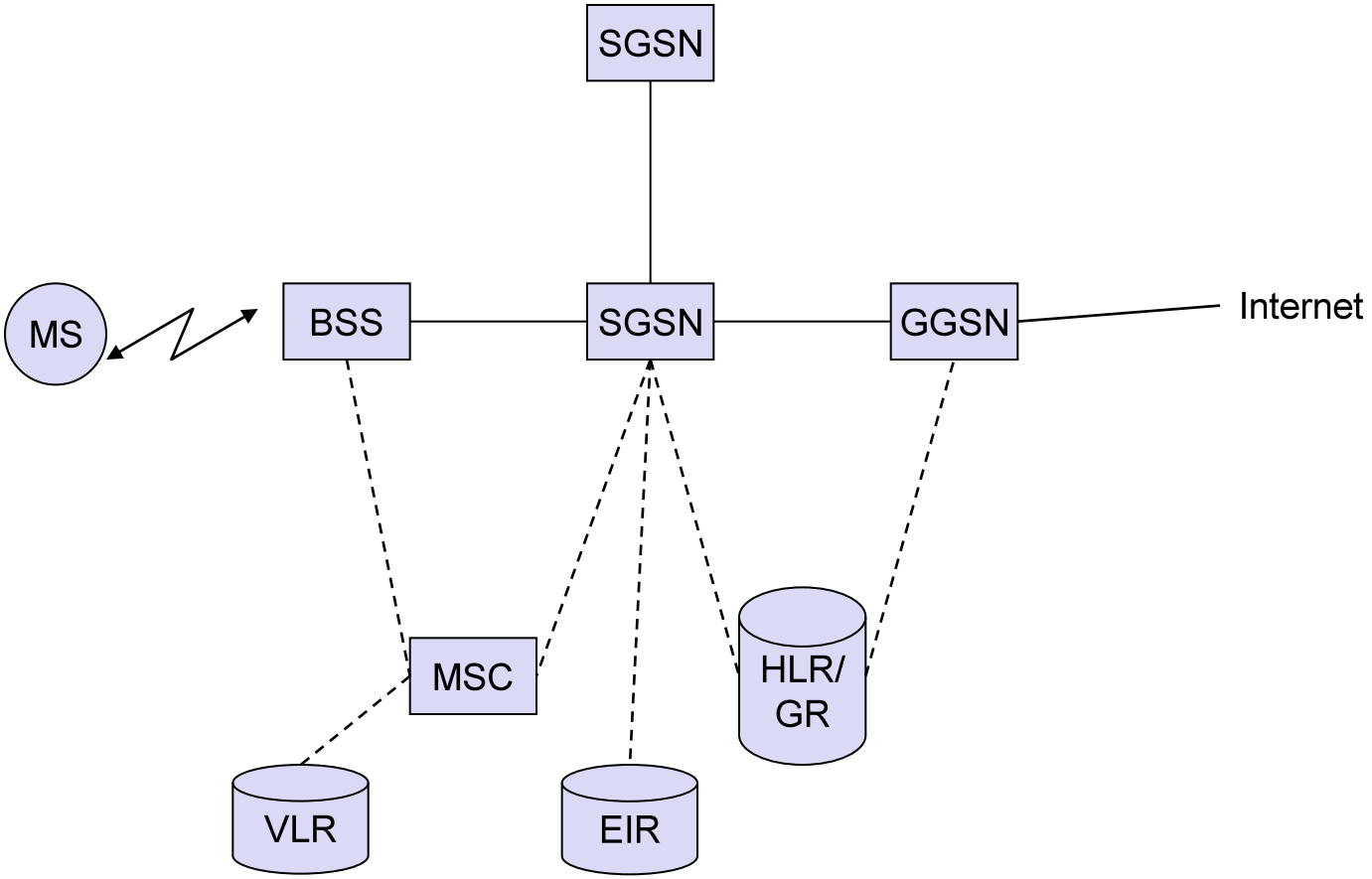


Hard handover

Data services in GSM

- GSM max 14.4kbps :-(
- GPRS (General Packet Radio Service) 2.5G
  - bonding of several channels (slots)
  - Hardware upgrade: duplex radio
  - Better MCS – up to 171Kbps
- EDGE (Enhanced Data rates for GSM Evolution)
  - Even better MCS – up to 384 kbit/s
- GPRS new network elements
  - GSN (GPRS Support Nodes): GGSN and SGSN
  - GGSN (Gateway GSN)
    - interworking unit between GPRS and PDN (Packet Data Network)
  - SGSN (Serving GSN)
    - supports the MS (location, billing, security)
  - GR (GPRS Register)
    - user addresses

GPRS architecture and interfaces



UMTS architecture

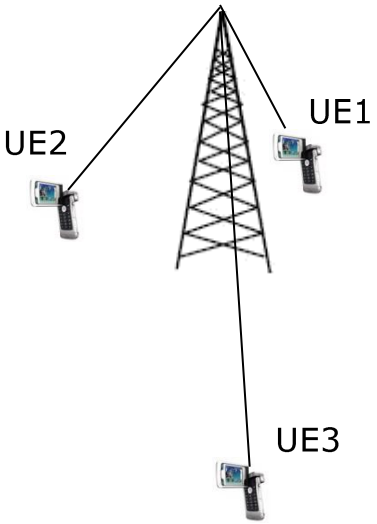
- UMTS Universal Mobile Telecommunications System 3G
- UTRAN (UMTS Terrrestrial Radio Access Network)
  - Cell level mobility
  - Radio Network Subsystem (RNS)
  - Encapsulation of all radio specific tasks
- UE (User Equipment)
- CN (Core Network)
  - Inter system handover
  - Location management if there is no dedicated connection between UE and UTRAN

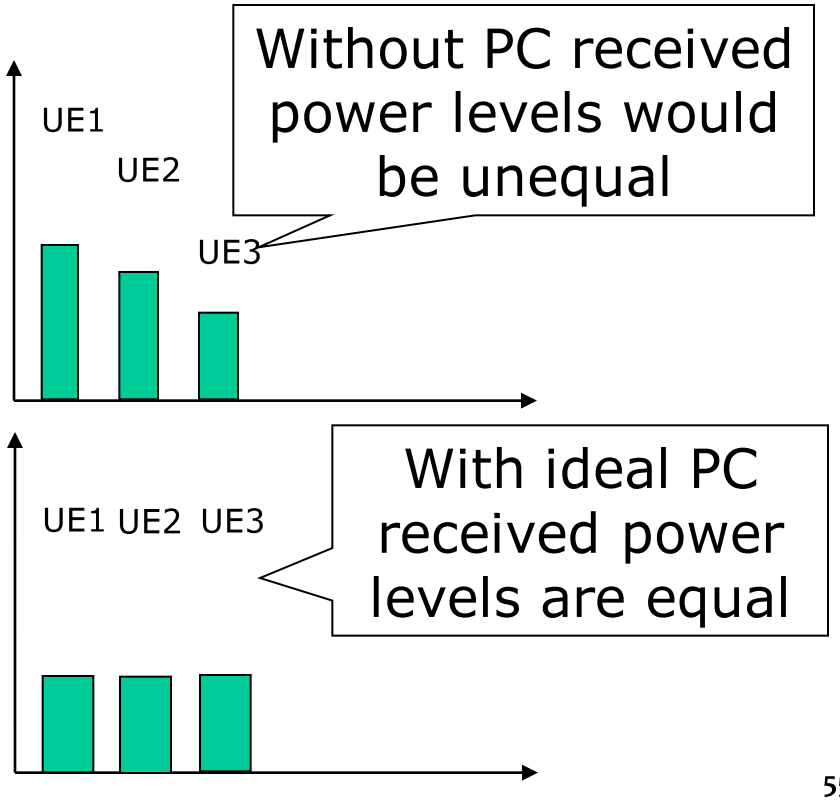
UMTS access

- CDMA + FDD, CDMA +TDD
- Downlink: No collisions
- Uplink: PRACH (physical random access channel)
  - Slotted ALOHA, *again!*
  - Power ramping
    - Start with low power
    - If no ACK, increase power
- Number of access slots
  - Defined per cell
  - Broadcast to all mobiles via BCH

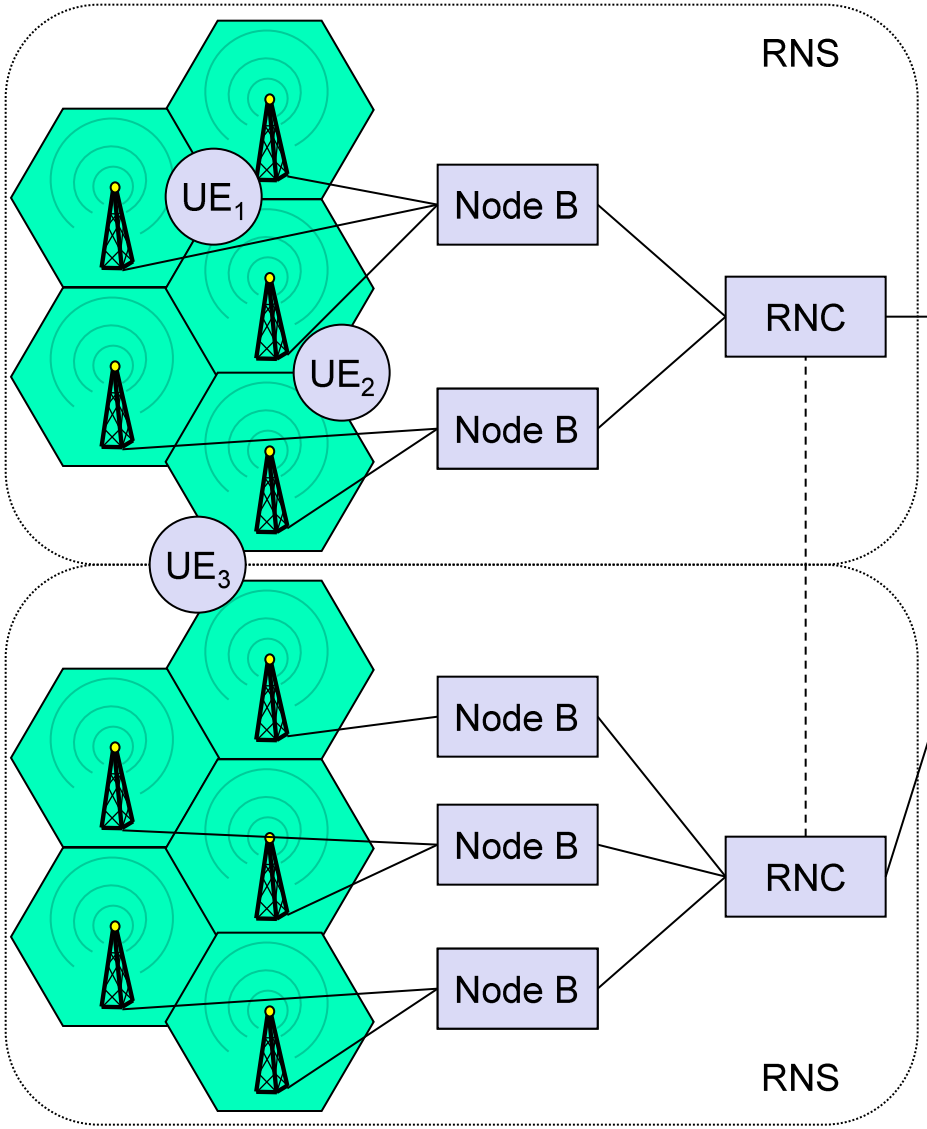
Power Control in CDMA

- power control (PC): ensure each user receives / transmits enough energy to have service but prevent:
  - Blocking of distant users (near-far-effect)
  - Exceeding reasonable interference levels





UTRAN architecture



RNC: Radio Network Controller

RNS: Radio Network Subsystem

- UTRAN comprises several RNSs
- RNC is responsible for handover decisions requiring signaling to the UE

UTRAN functions

RNC

- Admission/congestion control
- System information broadcasting
- Radio channel encryption
- Handover
- Radio network configuration
- Channel quality measurements
- Macro diversity
- Radio carrier control
- Radio resource control RRC
- Data transmission over the radio interface
- Outer loop power control (FDD & TDD)
- Channel coding
- Access control

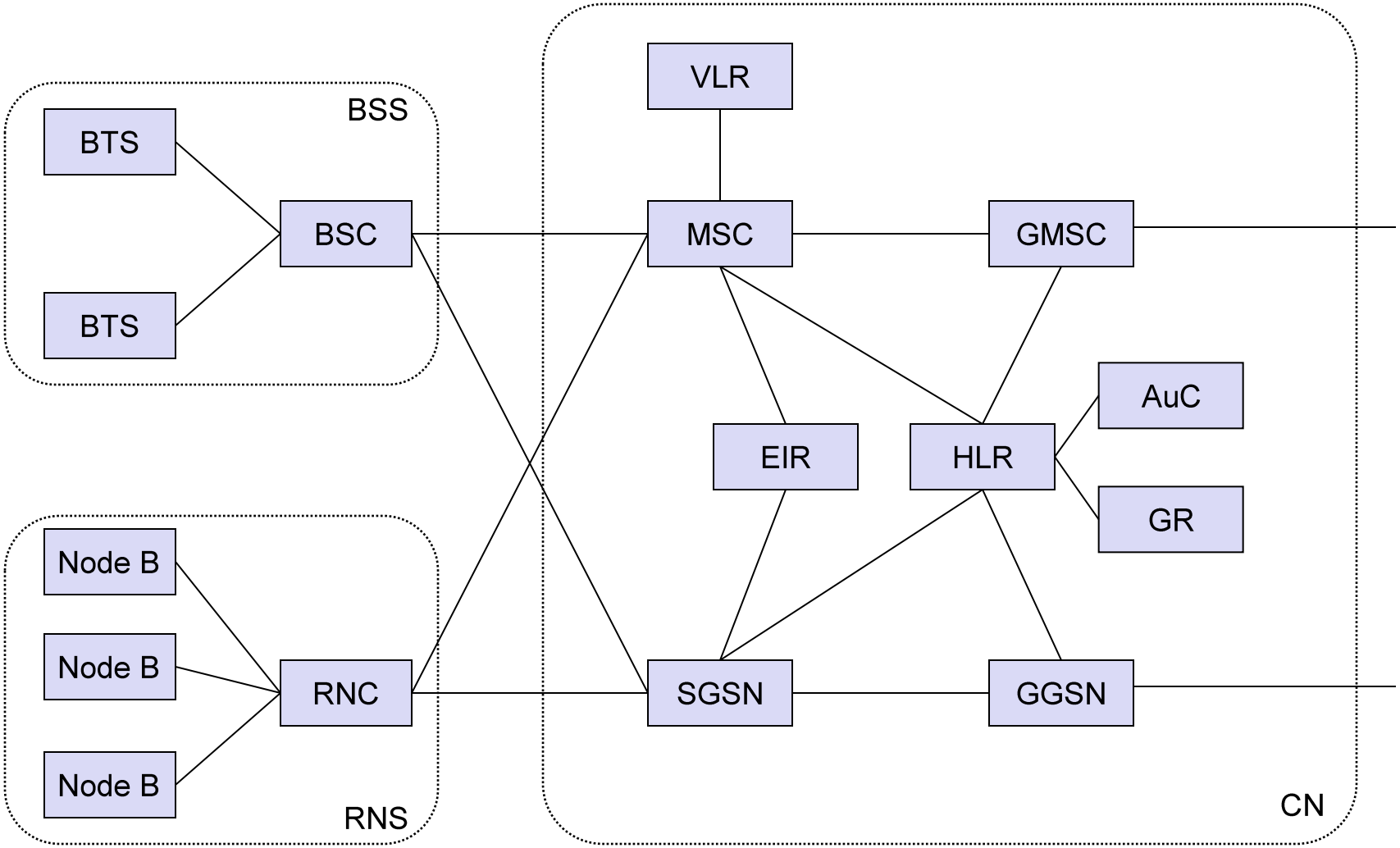
Node B

- Power control
- Handoff

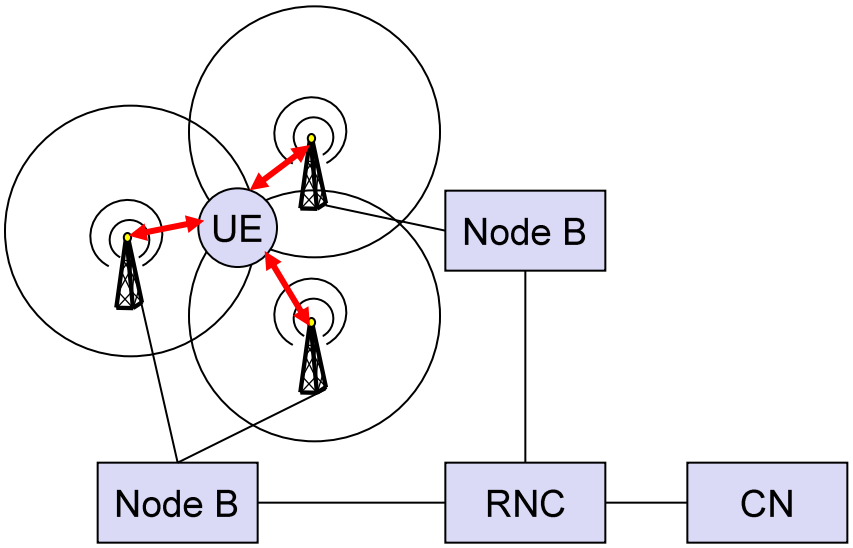
UE

- signal measurement
- Power control
- Handover, cell selection

Core network: 2G + 3G



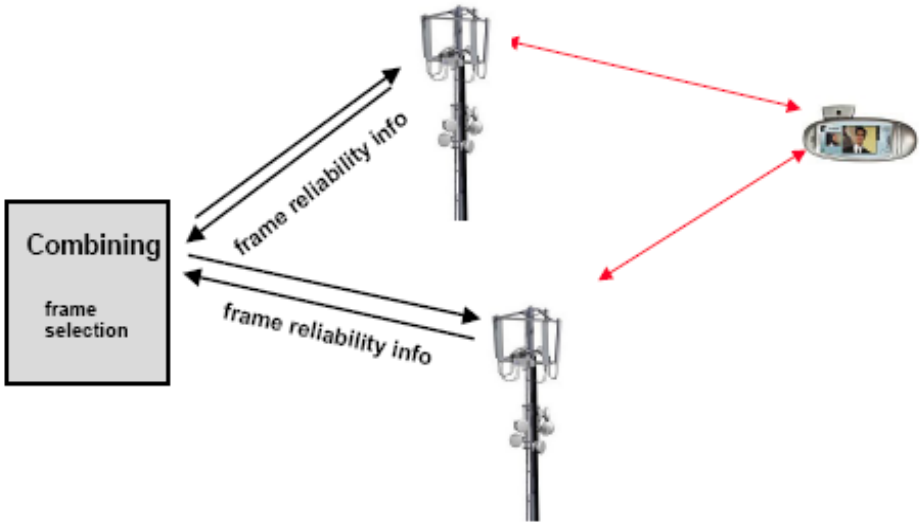
Support of mobility: macro diversity



- Multicasting of data via several physical channels
  - Enables soft handover
  - FDD mode only
- Uplink
  - simultaneous reception of UE data at several Node Bs
  - Reconstruction of data at Node B, or RNC
- Downlink
  - Simultaneous transmission of data via different cells
  - Different spreading codes in different cells

Soft handover

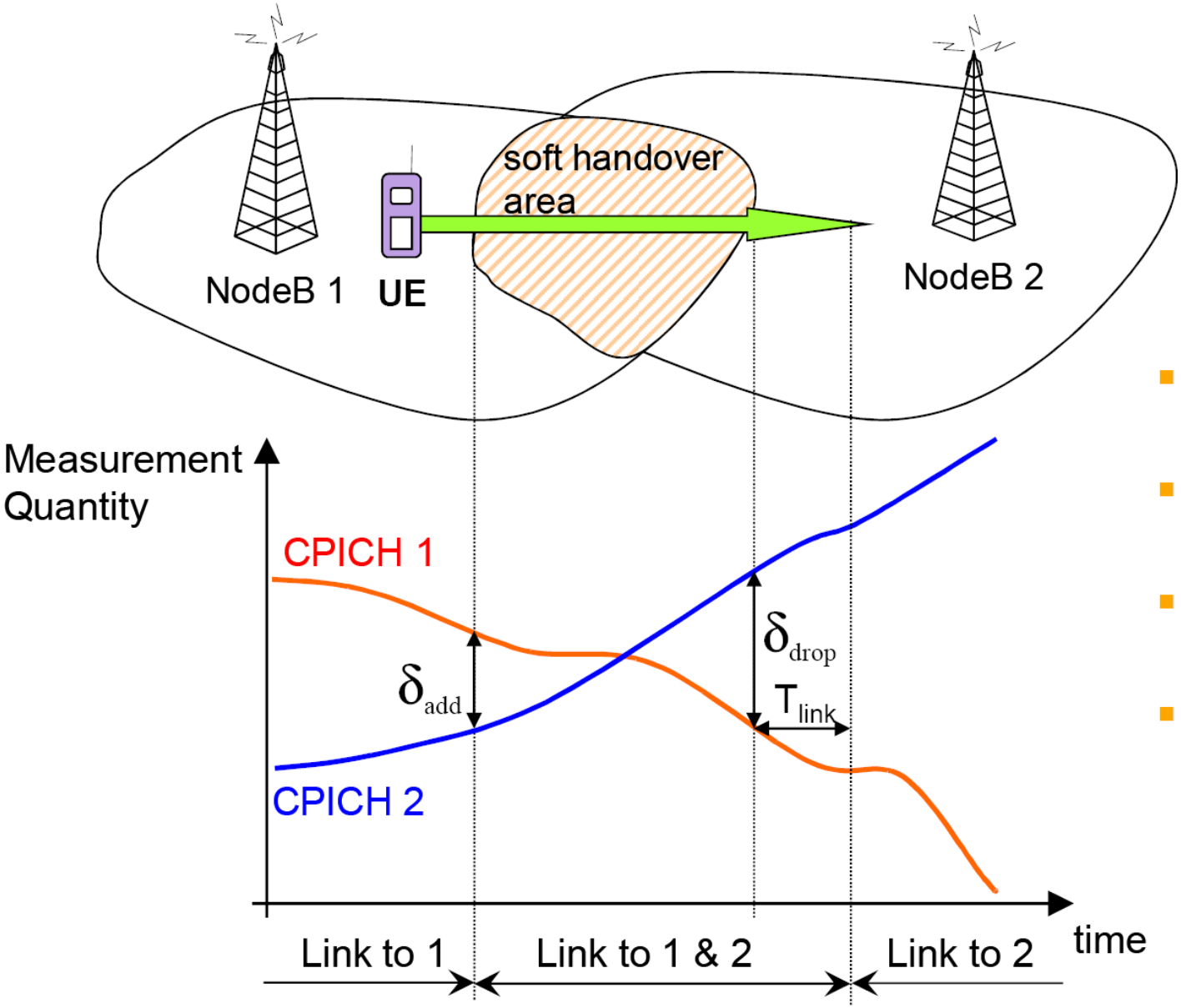
- Soft = no interruption
  - Handover between different Node Bs
  - Several Node Bs transmit the same signal to the UE which combines the transmissions



- Advantages
  - lower Tx power needed for each Node B and UE
  - lower interference, battery saving for UE

- Disadvantages
  - resources code&power to be reserved for UE in each Node B
  - Excess soft handovers limit the capacity
  - Needs RNC duplicating frame transmissions to two Node Bs

Soft handover



Some current UMTS enhancements

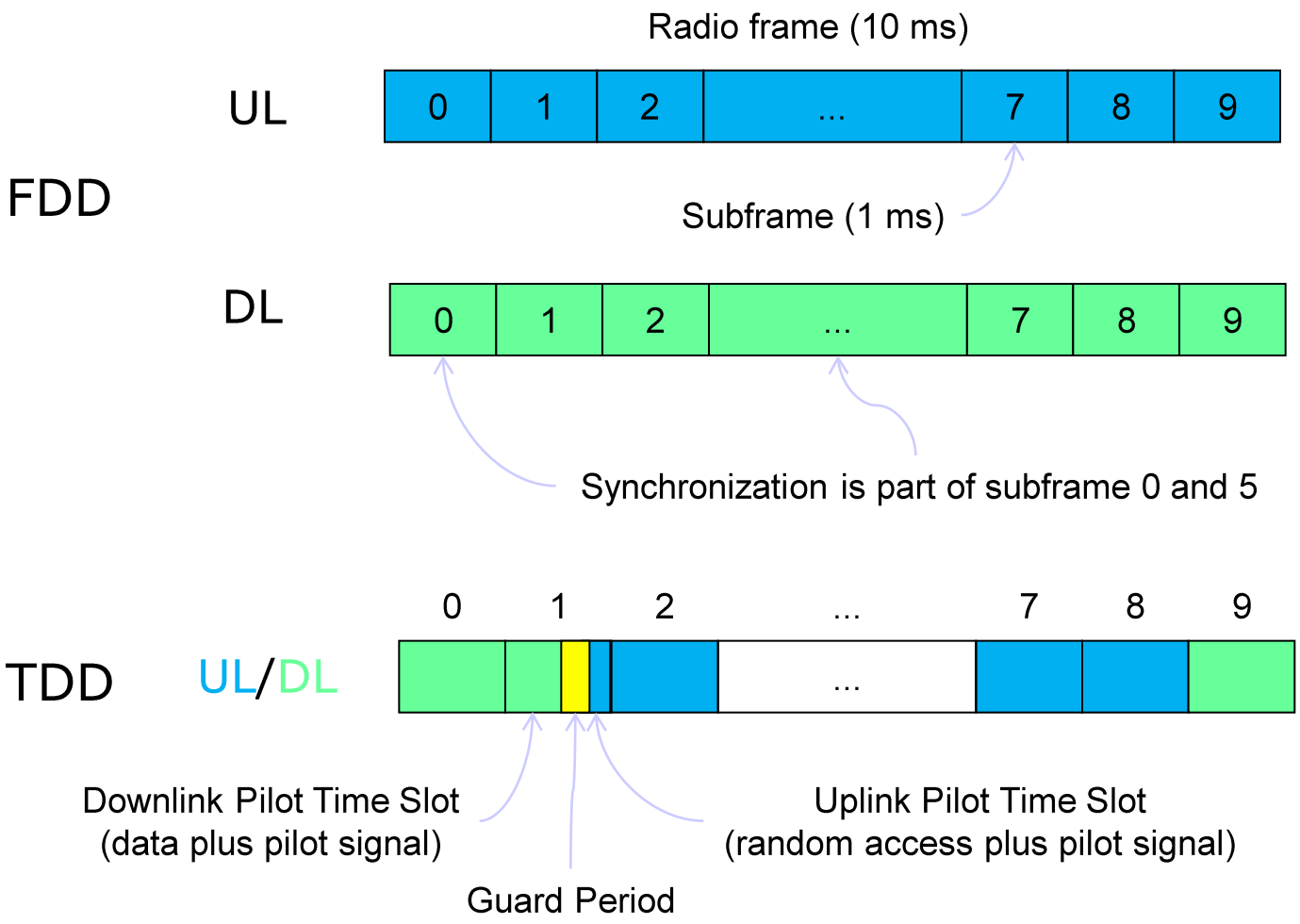
- HSPA (High-Speed Packet Access)
  - HSDPA 3.6, 7.2, 14.4, 21.6 Mbps
  - HSUPA 5.8Mbps
  - improved latency

- HSPA+ (Evolved HSPA)
  - Downlink 168Mbps
  - Uplink 22Mbps

Long Term Evolution (LTE)

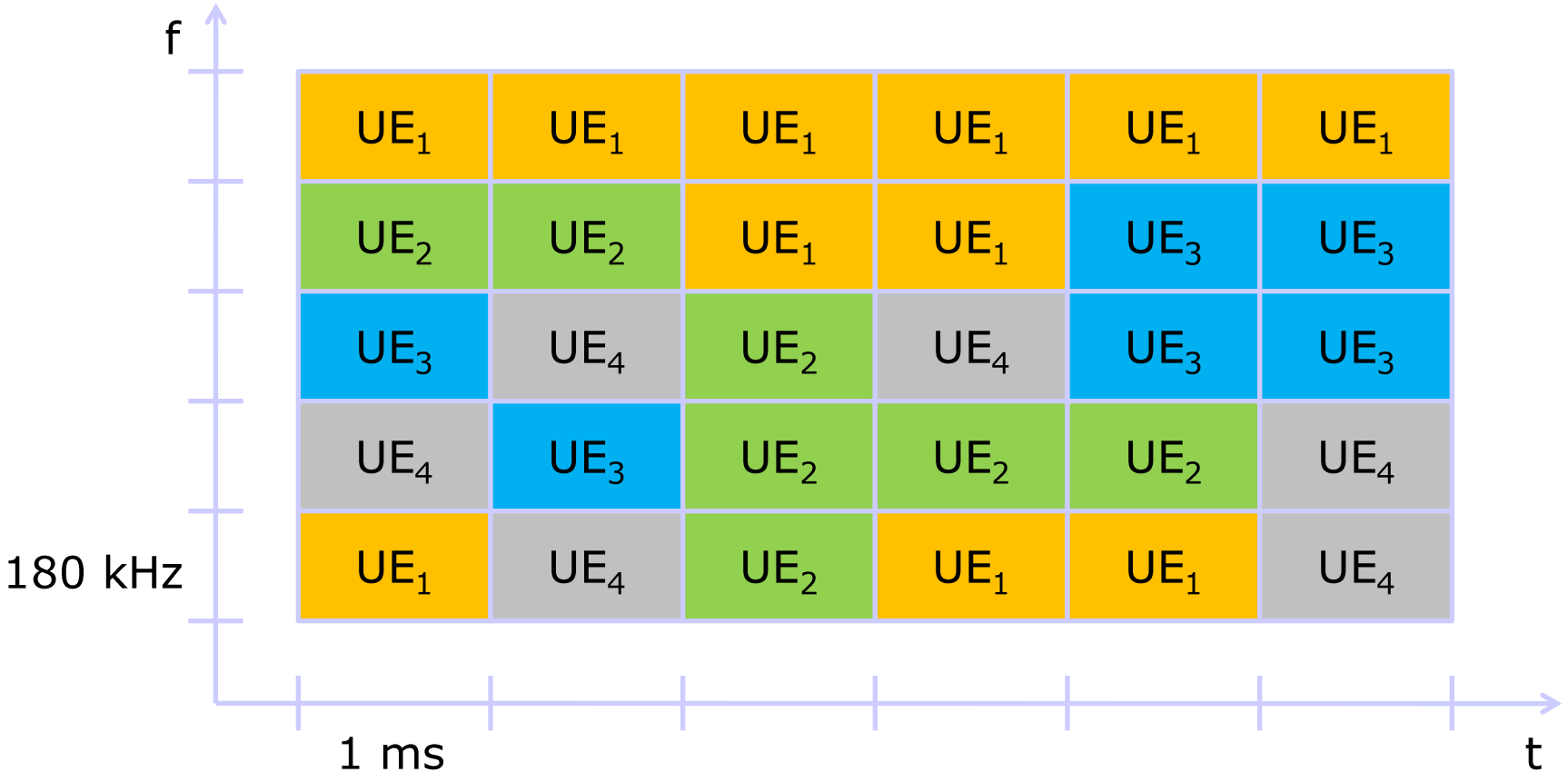
- Targets: Downlink 100 Mbit/s, uplink 50 Mbit/s, RTT<10ms
- 2012: LTE starts in Romania
- Simplified network architecture compared to GSM/UMTS
  - Flat IP-based network replacing the GPRS core, optimized for the IP-Multimedia Subsystem (IMS), no more circuit switching

LTE frame structure

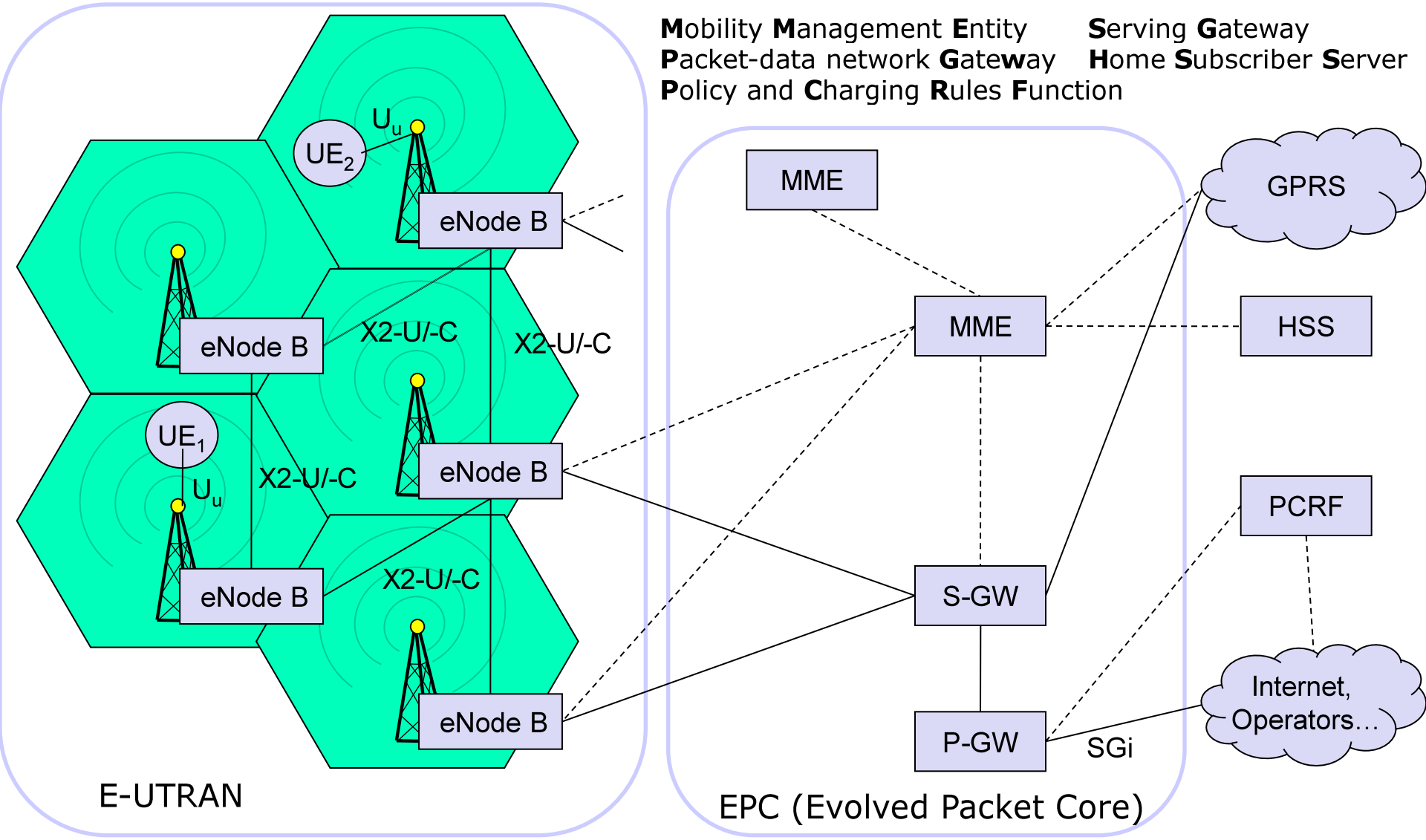


LTE multiple access

- **Scheduling of UEs in time and frequency (simplified)**



LTE architecture



Performance summary 2G 3G 4G

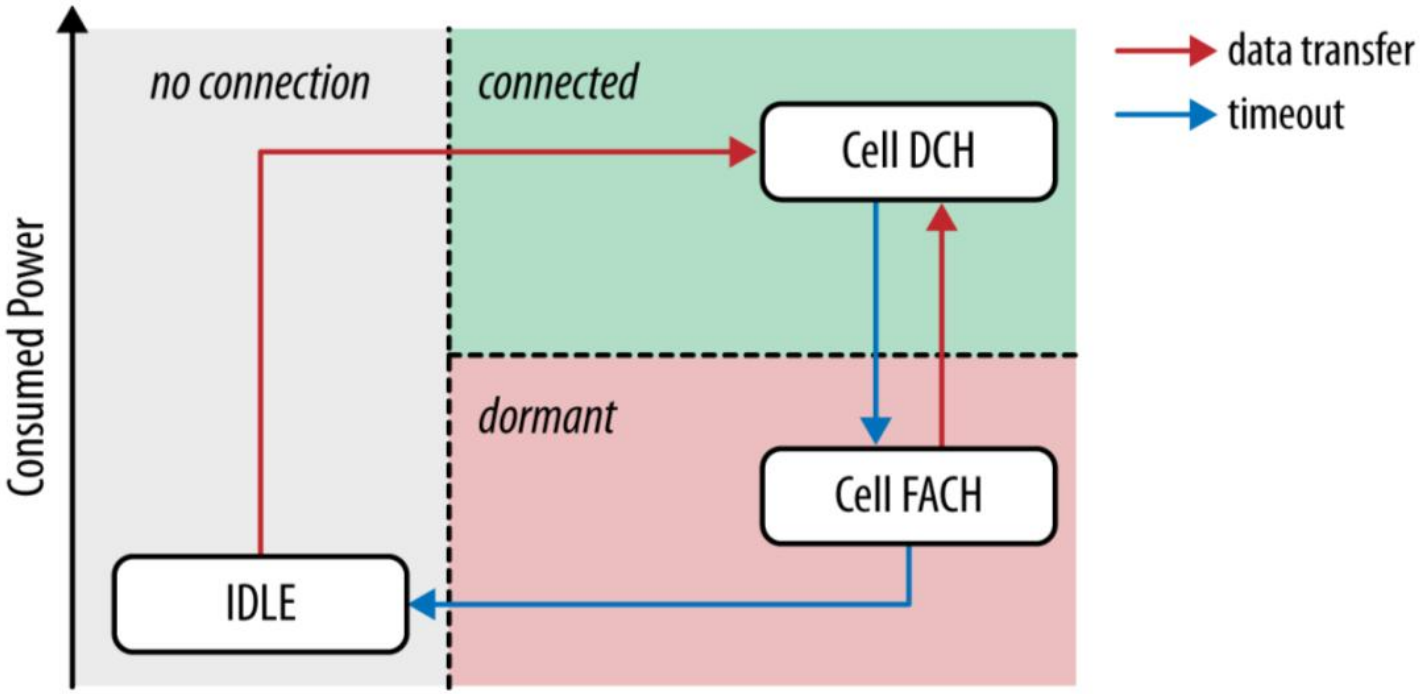
Technology	Throughput up/down [Mbps]	RTT [ms]	UE power (entire device)
GSM	0.0096/0.0096	1500	
GPRS	0.08/0.02	700	proportional
UMTS	0.384/0.384	200	0.8W, ~10s timers
HSPA	5.8/21.6	100	0.8W, ~10s timers
LTE	34/85	20	2W, ~10s timers

RRC = radio resource control

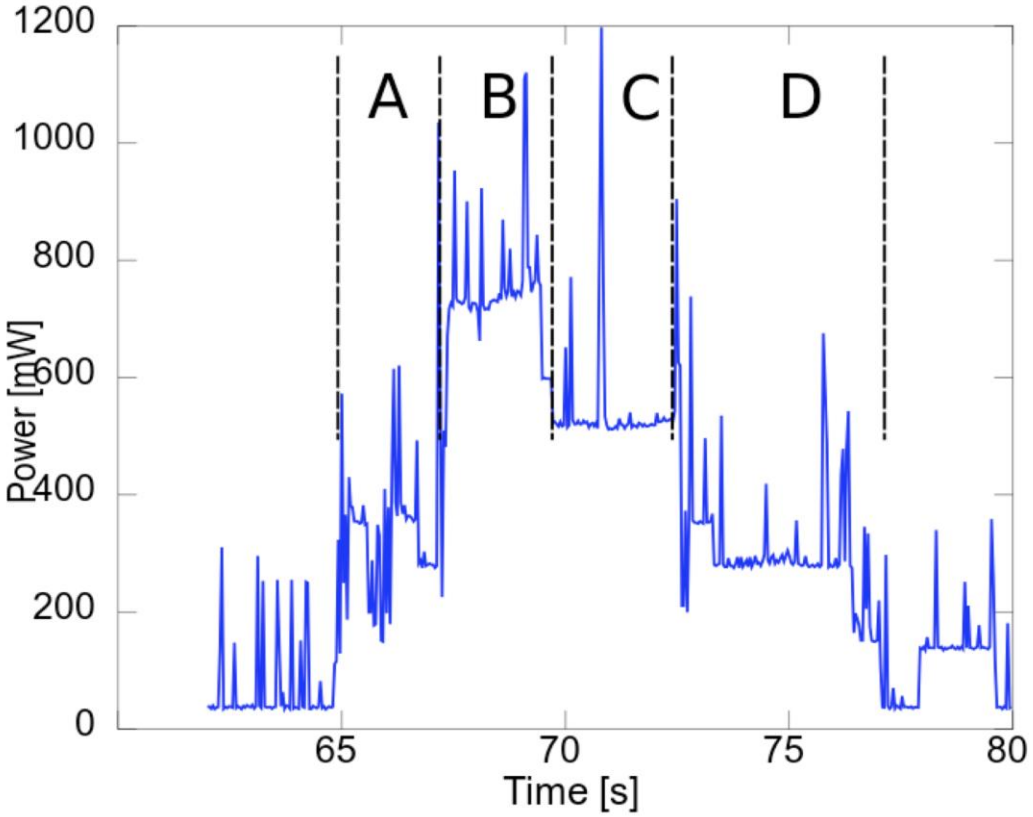
- tasks: setup, maintenance, release of radio channels
- performed by
  - BTS + BSC (GSM)
  - RNC (UMTS, HSPA)
  - eNodeB (LTE)

- has **MAJOR** role in
  - performance: latency and throughput
  - power consumption

UMTS RRC state machine



UMTS – UE power cosumption

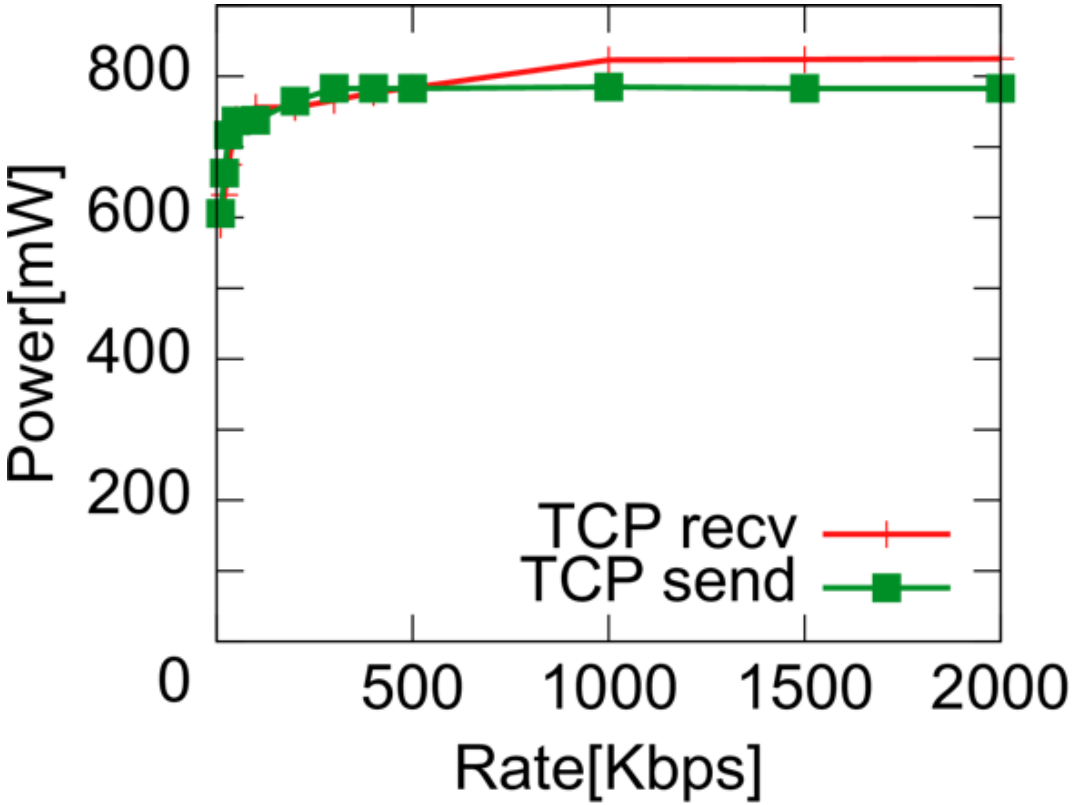


ping –c5 8.8.8.8

A: allocate channel
B: user traffic
C: DCH->FACH
D: FACH->IDLE

- RTT = 80..200ms
- 2s delay for sporadic traffic
- high power consumption for a single packet

UMTS – UE power cosumption

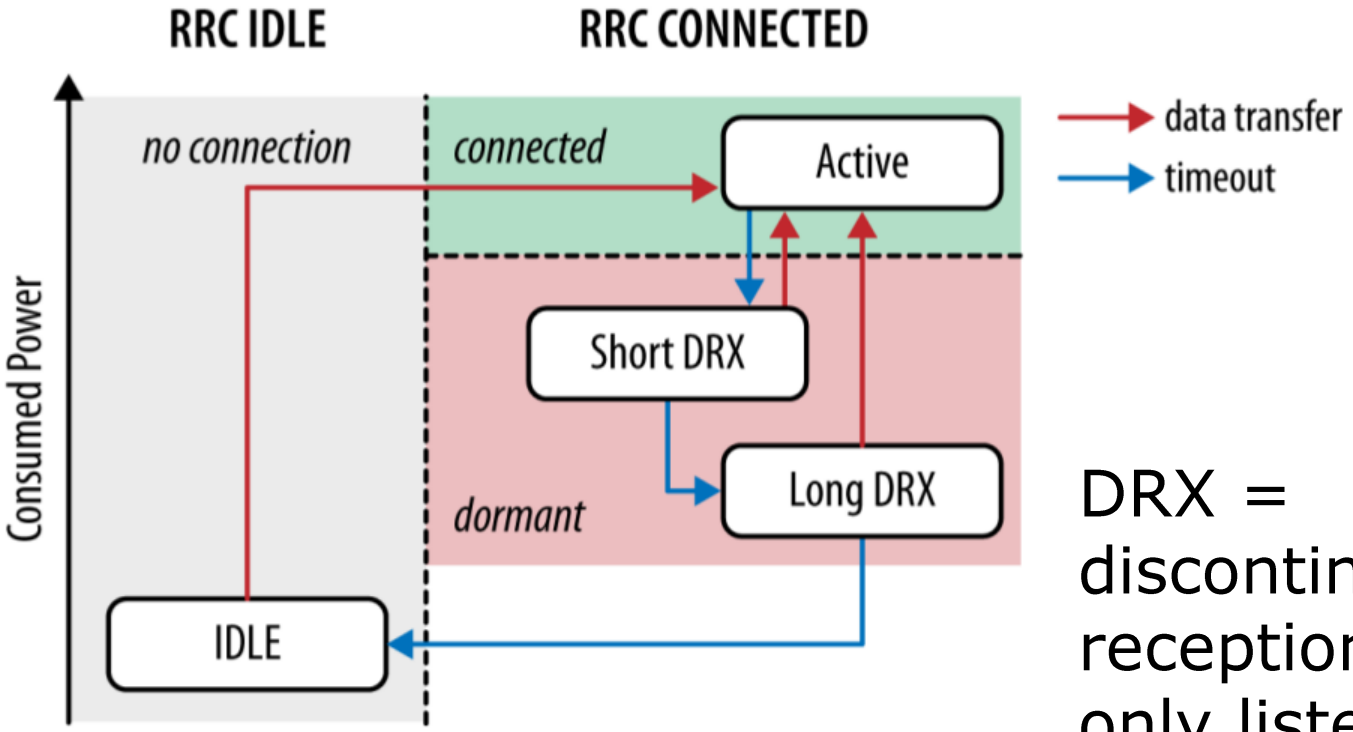


Samsung Galaxy Nexus
RDS, HSPA

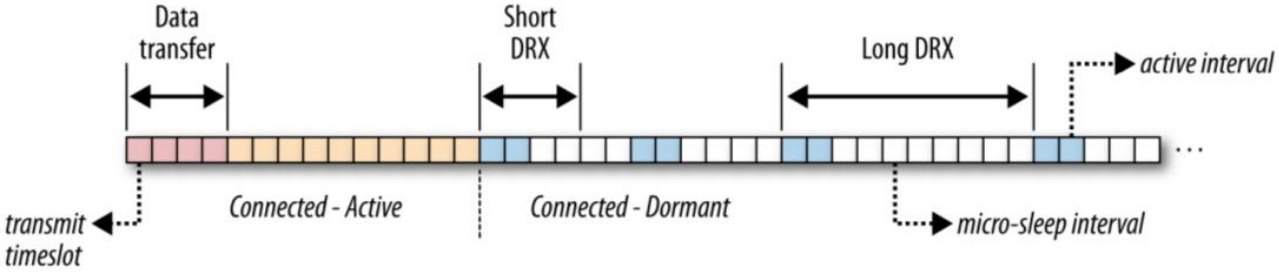
Screen off
TCP up: tc @ server
TCP down: curl –limit-rate

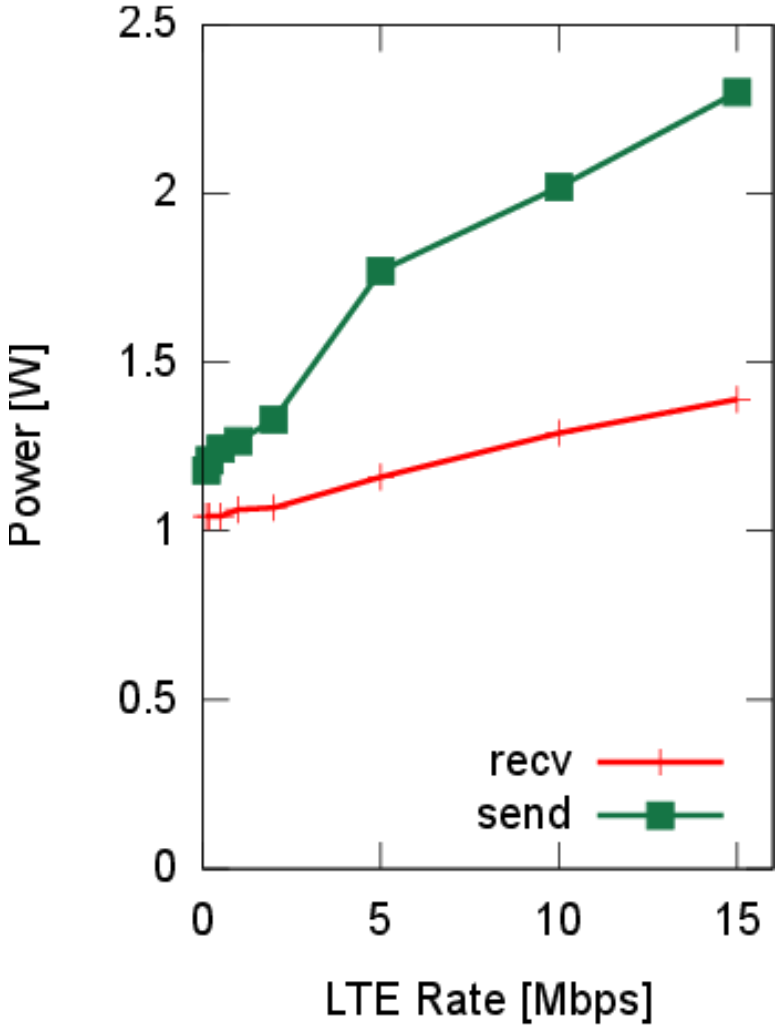
High efficiency **only** for highest rates

LTE RRC state machine



DRX = discontinuous reception
only listen to broadcasts





Samsung Galaxy Nexus
Orange LTE

Screen off
TCP up: tc @ server
TCP down: curl –limit-rate

Power/Performance summary

- RRC states are different for every standard
- RRC state machines are managed by the network
- RRC state promotions to high power occur when data must be transferred.
- RRC state demotions to lower power occur on network-configured timeouts.
- LTE/HSPA+ state transitions can take 10 to 100ms
- HSPA/CDMA state transitions can take several sec

- every network transfer, **no matter the size, incurs an energy tail.**

“new” developements

(nu se cere la examen)

- **Femtocells**
- **Mobile offloading**
- **Mobile edge cloud**
- **5G**

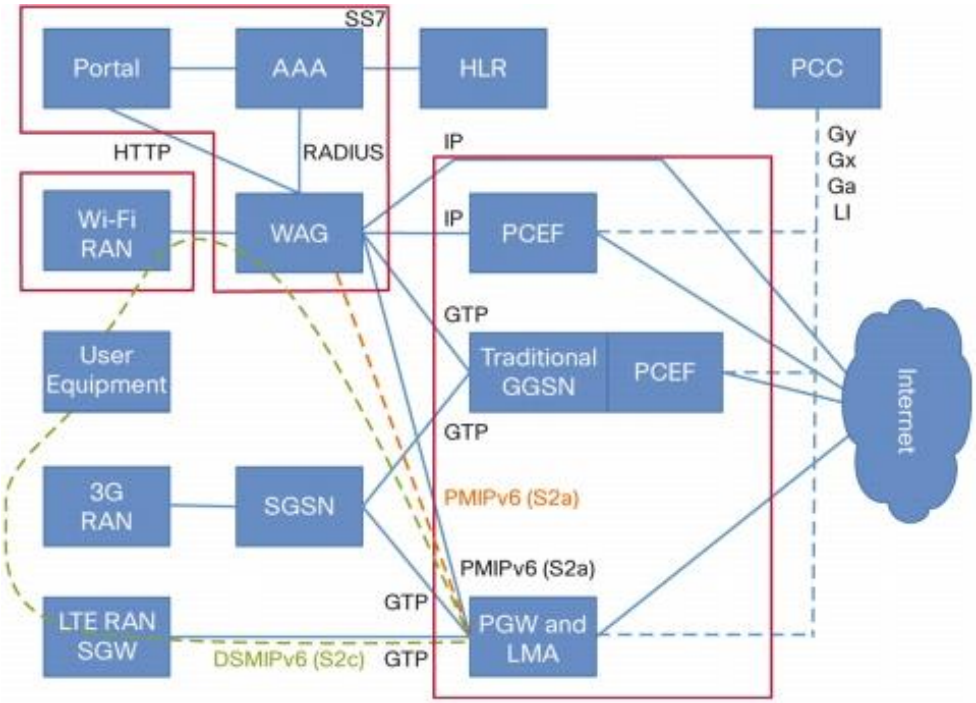
Femtocells

- more consumers use mobiles at home, even when there's a fixed line available
  - full mobile residential coverage -- significant challenge

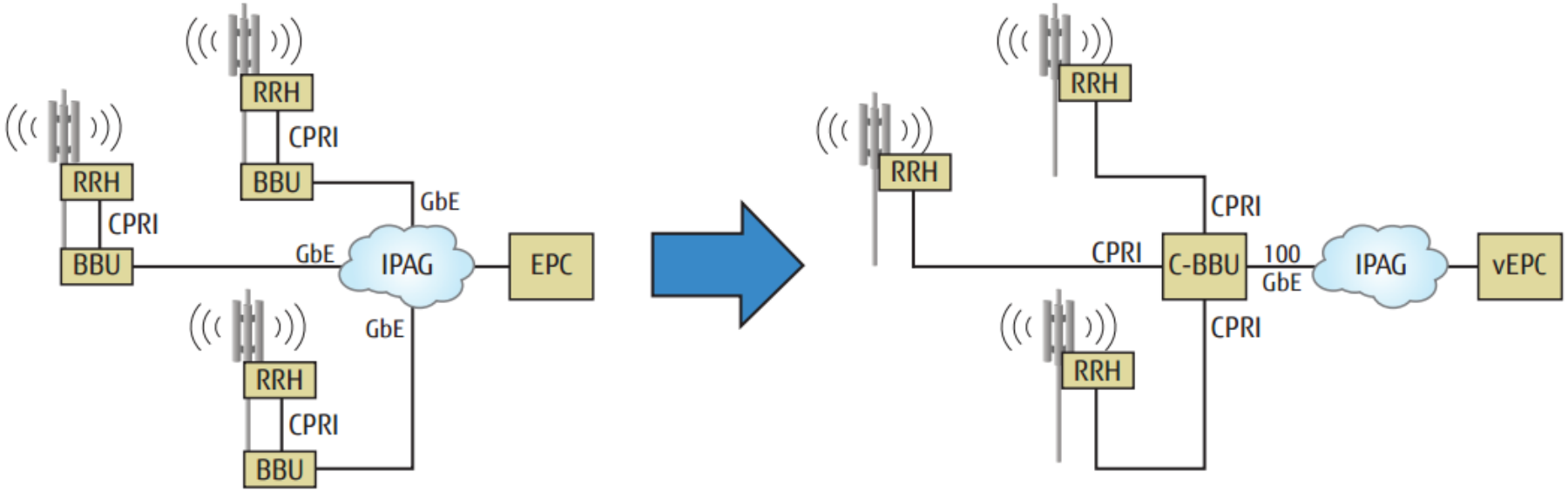
- very small indoor, home and campus NodeB layouts
- Femtocells are cellular access points (for limited access group) that connect to a mobile operator's network using residential DSL or cable broadband connections
- Femtocells enable capacity equivalent to a full 3G network sector at very low transmit powers, dramatically increasing battery life of existing phones, without needing to introduce WiFi enabled handsets

Mobile offloading

- The technology evolution of radio access networks is limited by the laws of physics
- Wi-Fi - small cell technology
- Untrusted offloading: any WiFi infrastructure
- Trusted offloading: operator's WiFi infrastructure
  - Authentication with SIM (EAP-SIM/AKA)



Cloud RAN



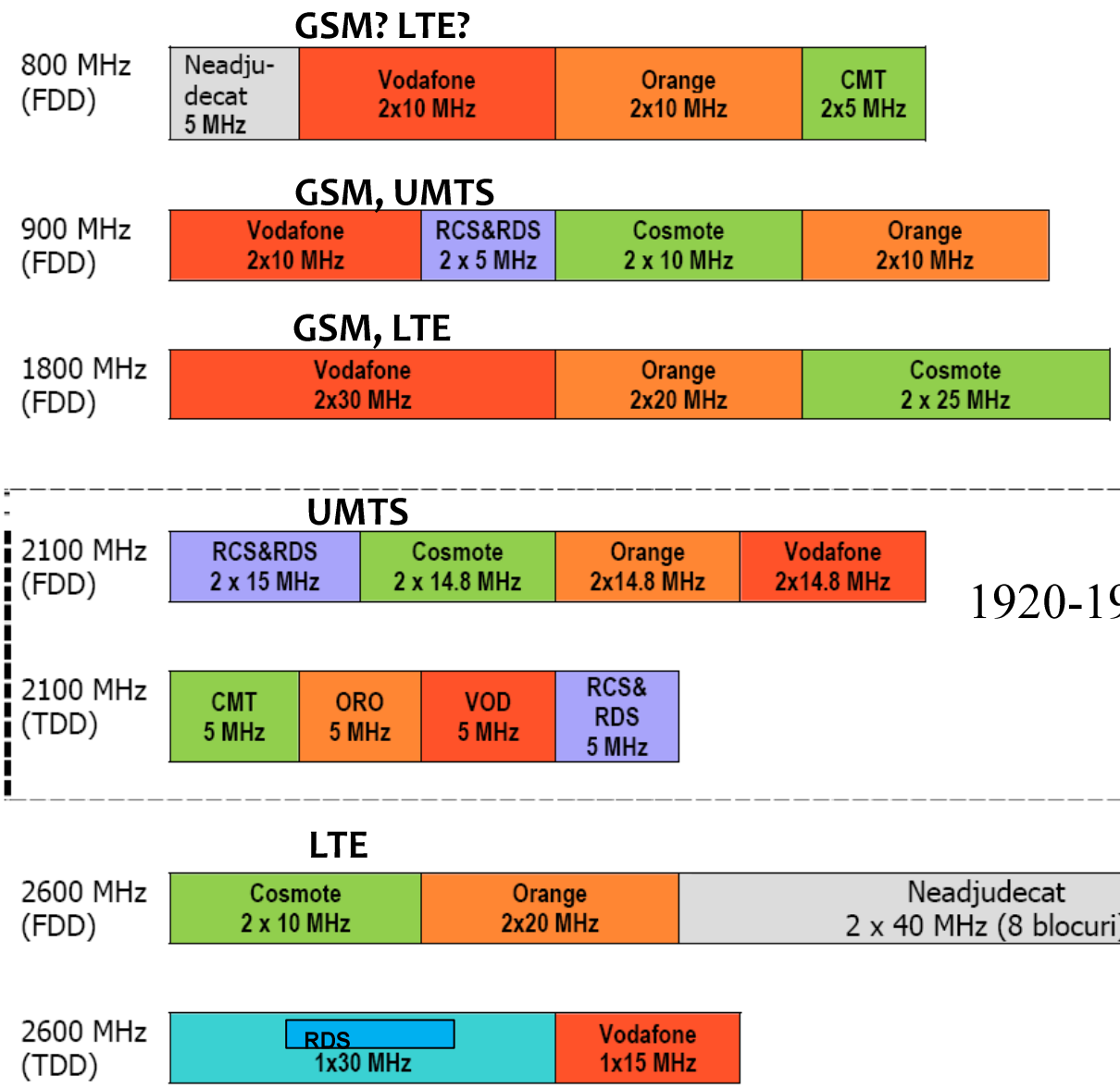
Cloud takes over PHY
RAN = Radio Access Network
RRH = Remote Radio Head
BBU = Baseband Unit
EPC = Evolved Packet Core
GbE = Gigabit Ethernet

Piața telecom în România

(nu se cere la examen)

Sursa:
Date ANCOM, document 2014/02/01/RO

Spectrum auction Romania



Licitație 2012 = 682M€

Cosmote = 180M€

Orange = 227M€

Vodafone=228M€

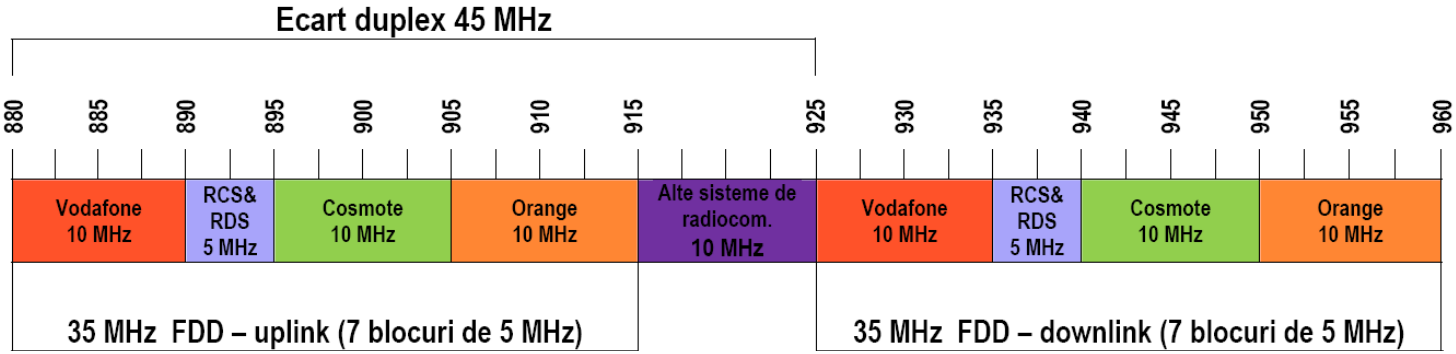
RDS=40M€

2K=6M€

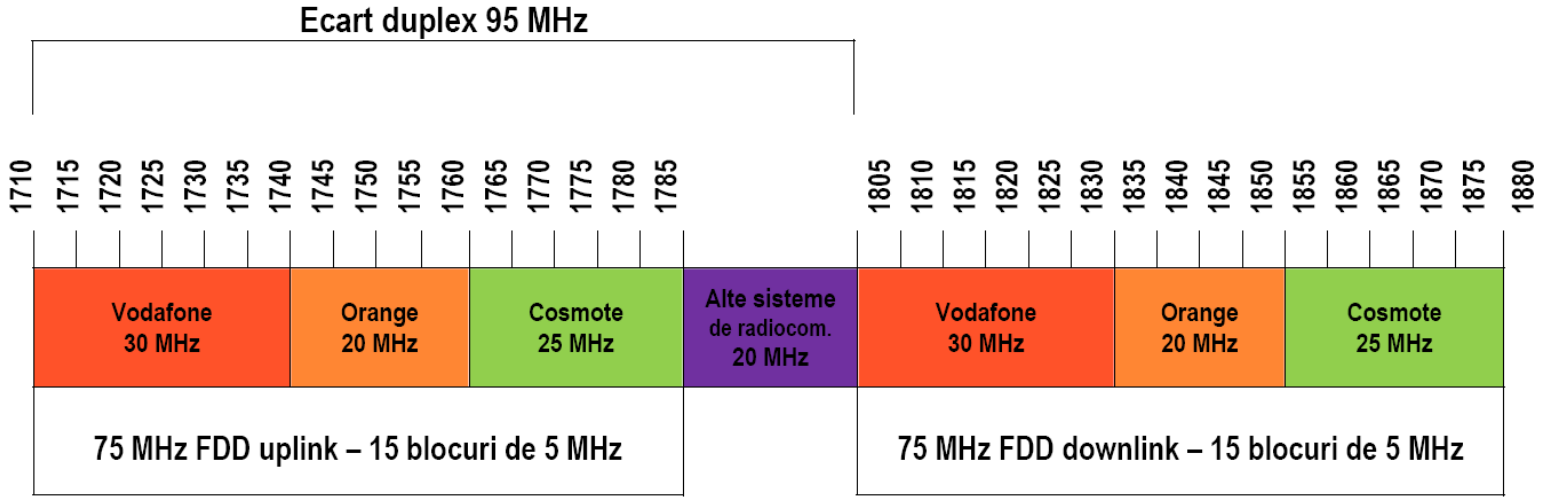
1920-1980, 2110-2170 MHz

GSM la 900MHz și 1800MHz

Benzile 880 – 915 MHz / 925 – 960 MHz
- alocări valabile în perioada 06.04.2014 – 05.04.2029 -

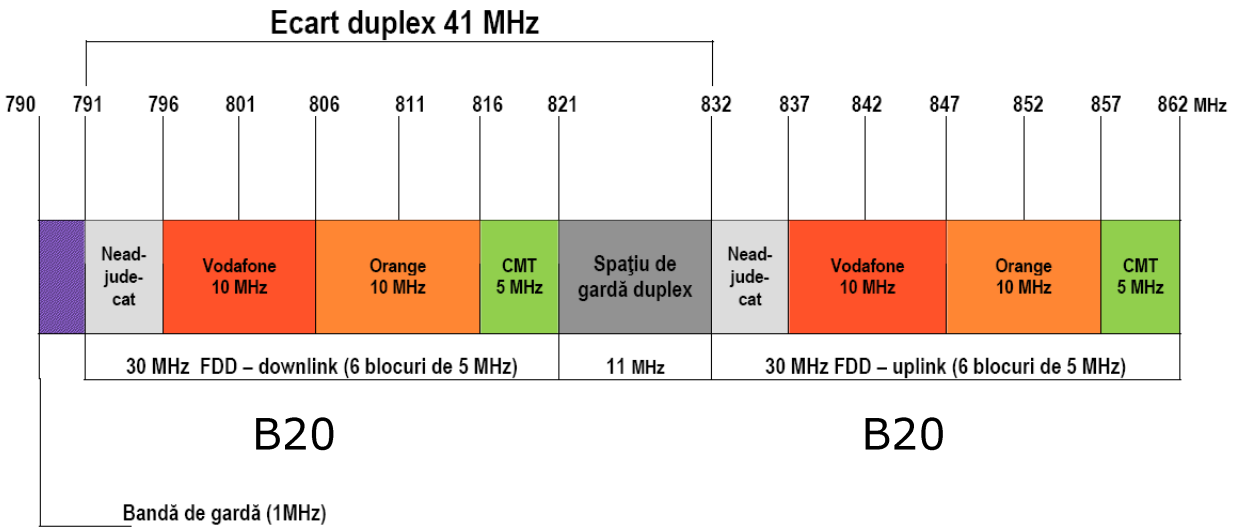


Benzile 1710 - 1785 MHz / 1805 - 1880 MHz
- alocări valabile în perioada 06.04.2014 – 05.04.2029 -



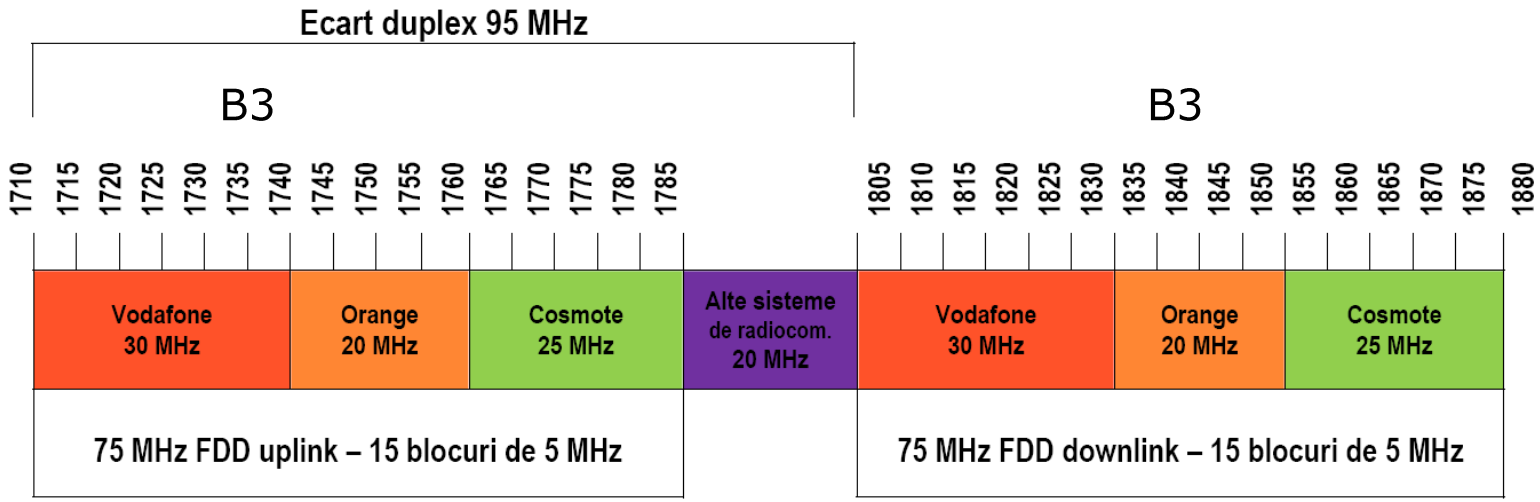
LTE 800MHz

Benzile 791 – 821 MHz / 832 – 862 MHz
- alocări valabile în perioada 06.04.2014 – 05.04.2029 -

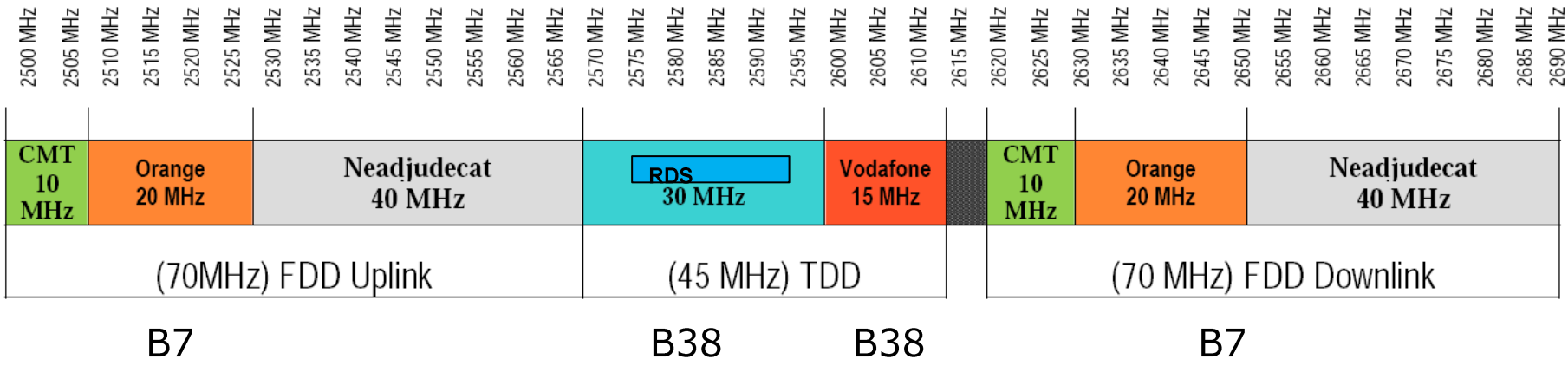


FDD pentru LTE

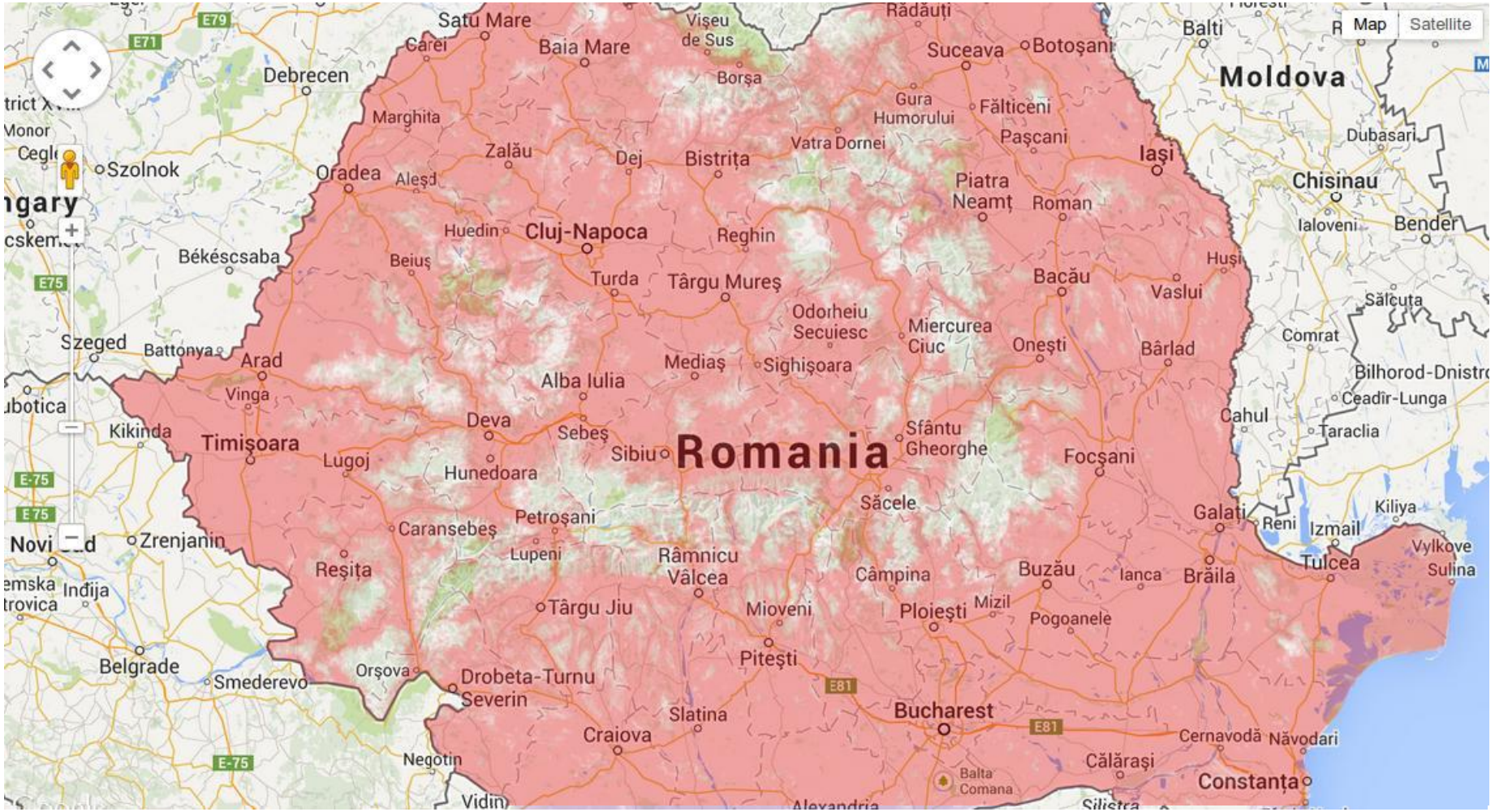
Benzile 1710 - 1785 MHz / 1805 - 1880 MHz
- alocări valabile în perioada 06.04.2014 – 05.04.2029 -



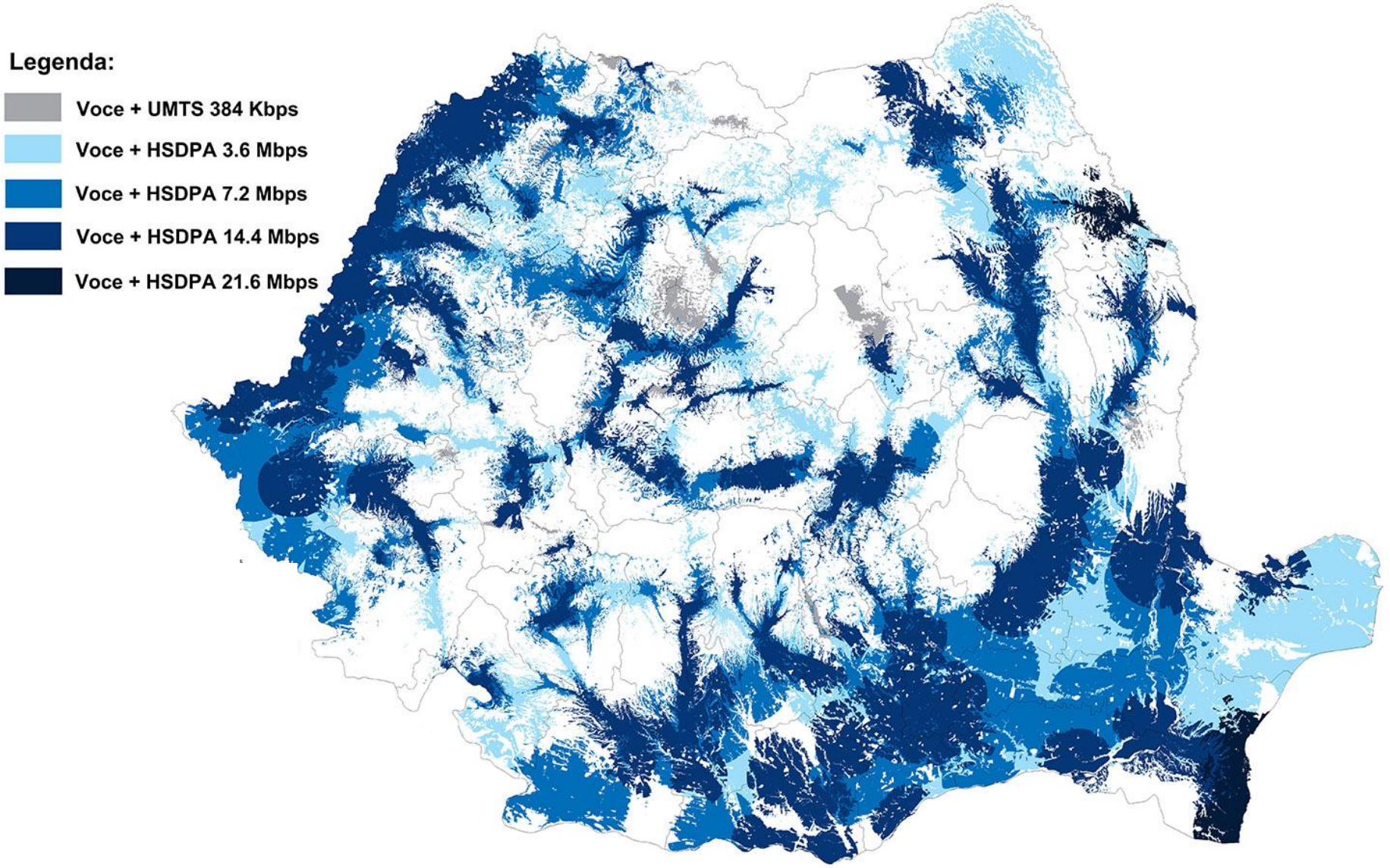
Banda de frecvenţe 2500 – 2690 MHz
- alocări valabile în perioada 06.04.2014 – 05.04.2029 -



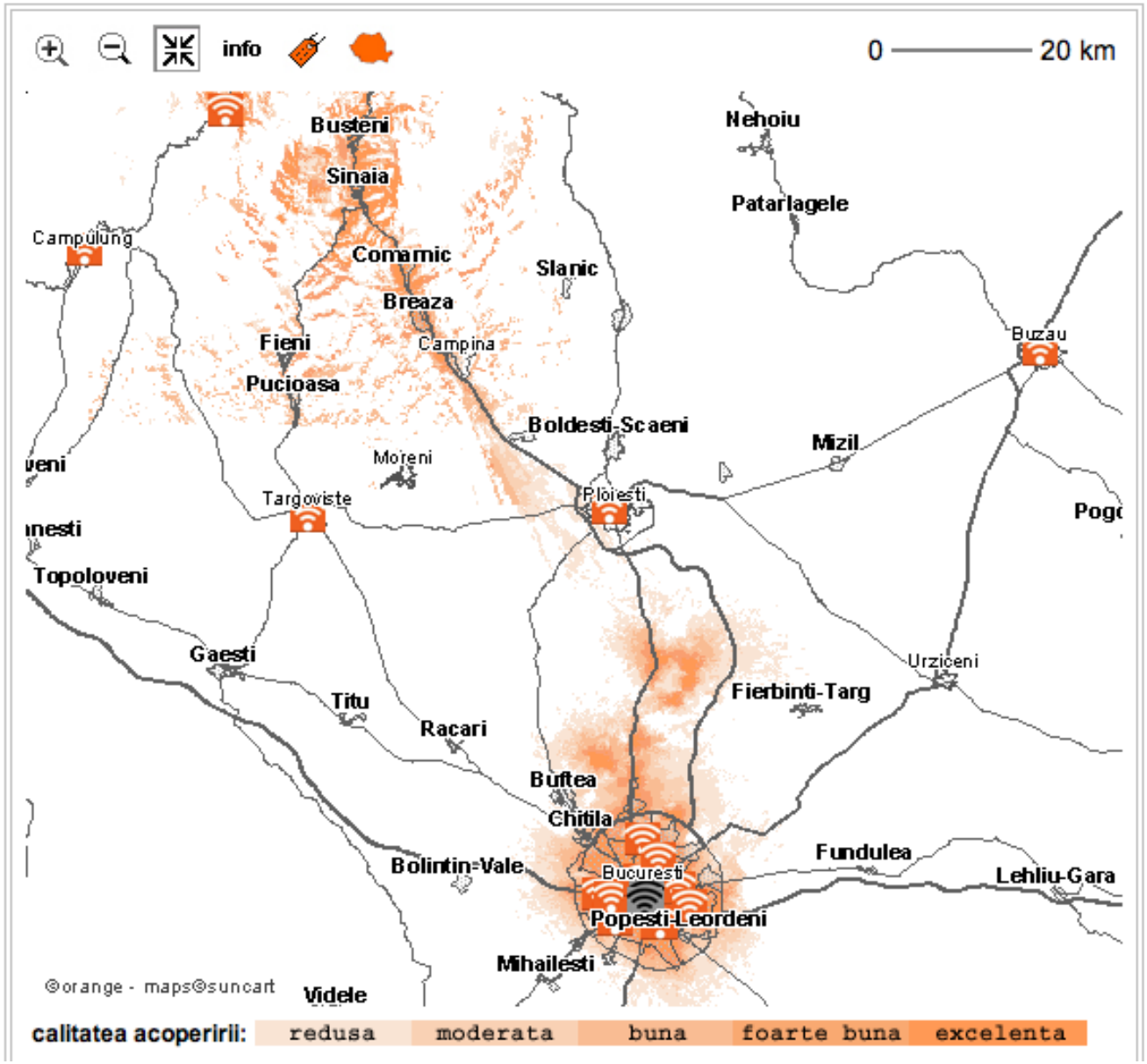
Acoperire Vodafone 2G, 2014



Acoperire RDS 2014: 2100MHz, 900MHz



LTE în România/Orange, 2014



LTE în România/Vodafone, 2014