Infokommunikációs rendszerek – Infocommunication systems

Lesson 6. előadás

Basics of mobile networks

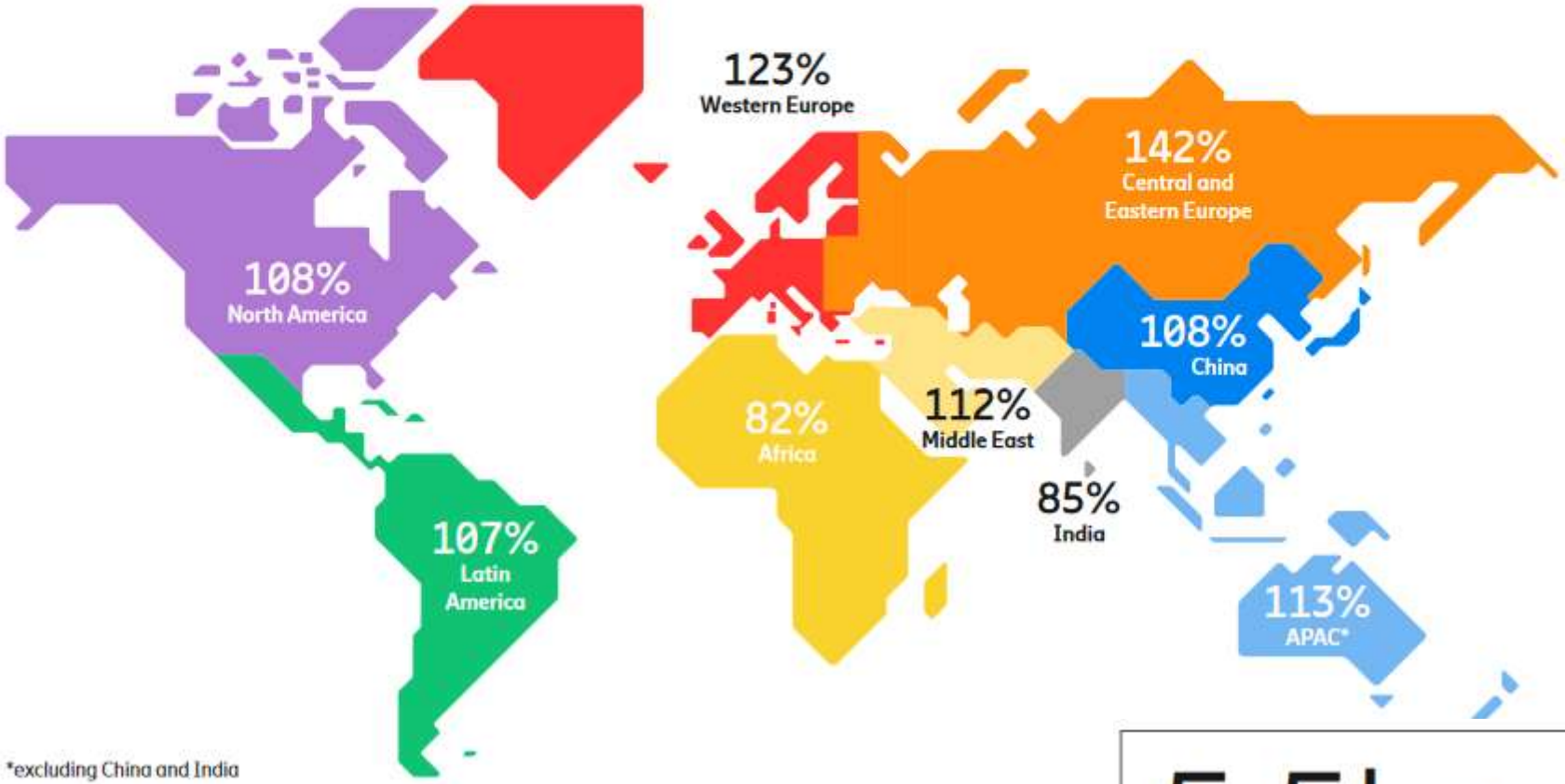
Mobil hálózatok alapjai

Takács György

In Q2 2018, the total number of mobile subscriptions
was around 7.8 billion, with a net reduction of 13 million subscriptions globally.

103%

103 percent global subscription penetration in Q2 2018.



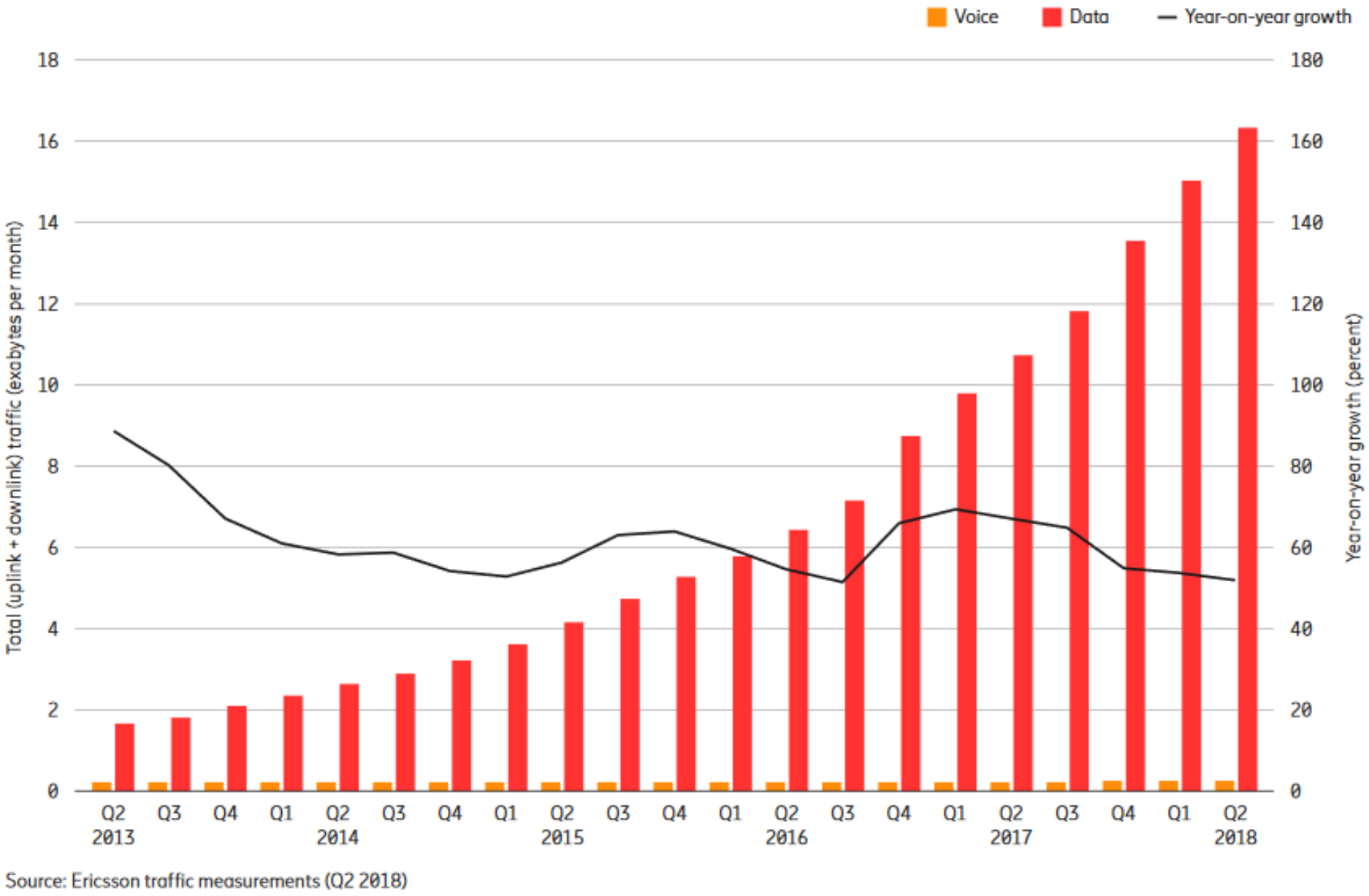
5.5bn

There are now 5.5 billion mobile broadband subscriptions globally.

Infokom. 6. 2018. 10. 15.

https://www.ericsson.com/assets/local/mobility-report/documents/2018

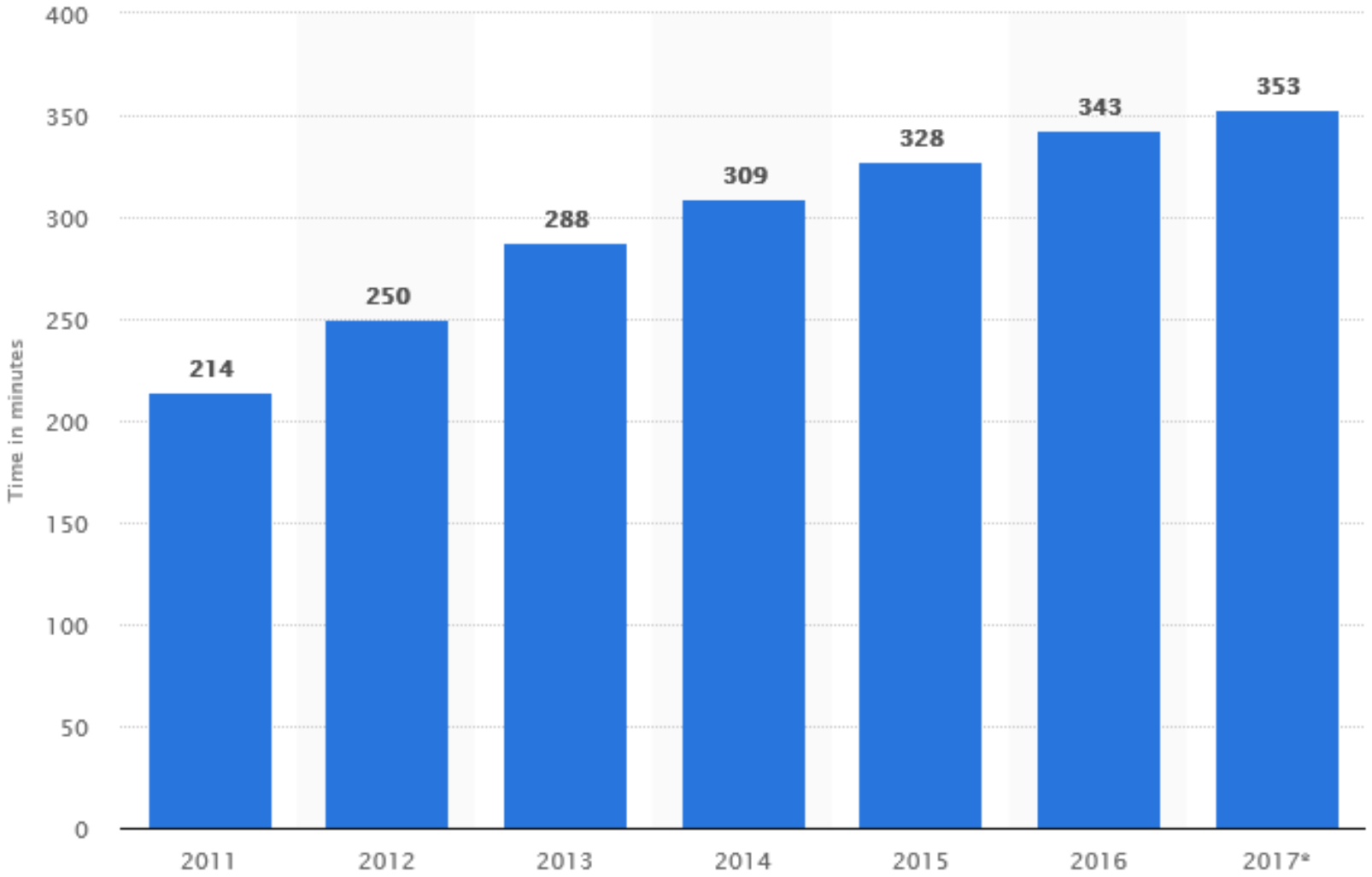
- 2 billion people have no healthy tap water
- many of them has mobile phone



Source: Ericsson traffic measurements (Q2 2018)

exabájt1 EB = 10^{18}bájt = 1000 petabájt = 1millió terabájt = 1milliárd gigabájt.

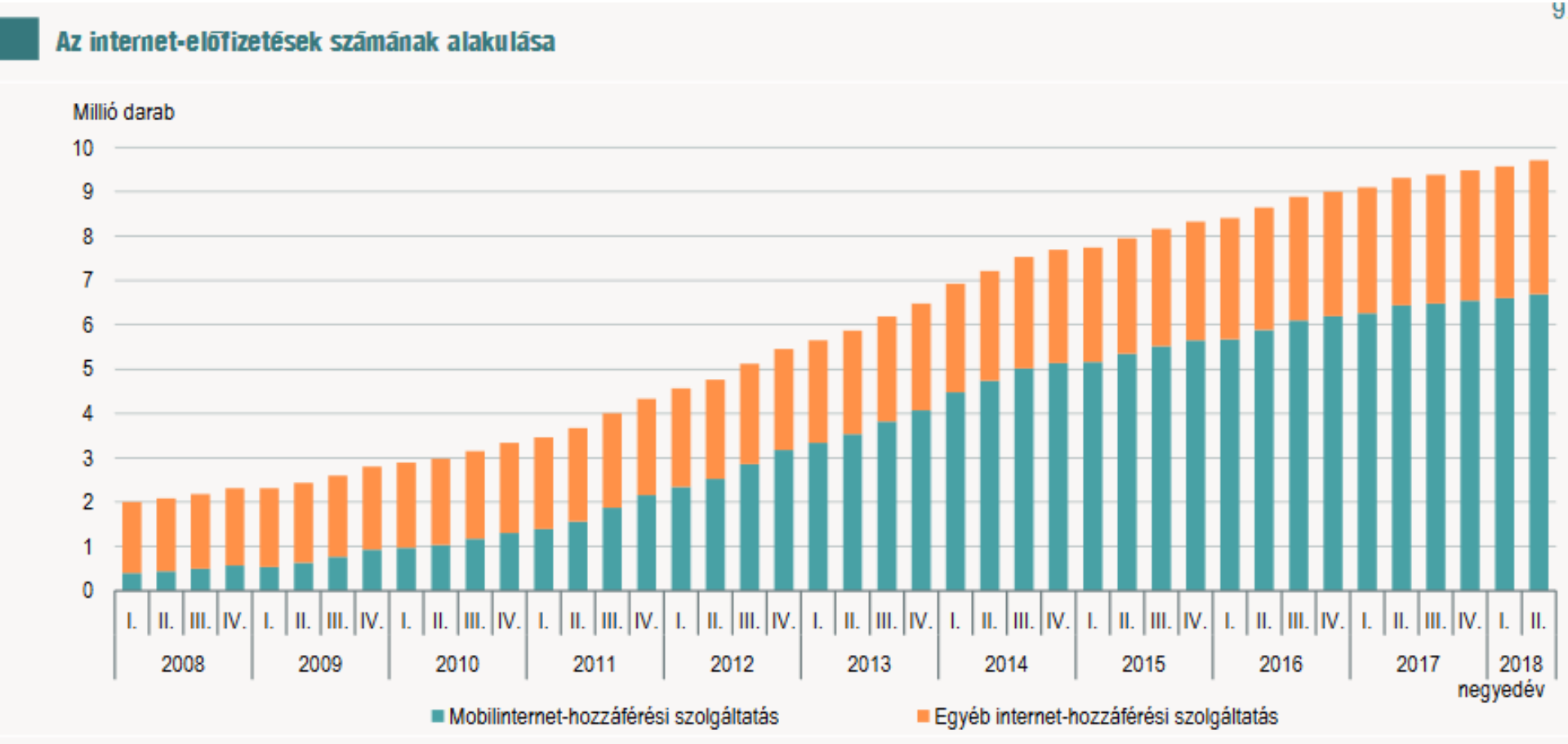
Time spent per day with digital media in the United States



KSH STATISZTIKAI TÜKÖR 2018. szeptember 11.

- 2018. II. negyedév végén a mobiltelefon-előfizetések száma 11,9 millió volt, egy év alatt 39 ezerrel emelkedett. A teljes állományon belül a havi-díjas előfizetések száma 442 ezerrel (6,0%-kal) nőtt, és megközelítette a 7,8 milliót. 2017 elején életbe lépett a feltöltőkártyás előfizetések ellenőrzését meghatározó hatósági rendelet, amely előírja a kötelező adat-egyeztetést az előfizetők számára.

KSH STATISZTIKAI TÜKÖR 2018. szeptember 11.



Letöltés Kínált legnagyobb sávszélesség	**30 Mbit/s**	**300 Mbit/s**
Feltöltés Kínált legnagyobb sávszélesség	**10 Mbit/s**	**50 Mbit/s**
Garantált letöltési és feltöltési sebesség az esetek 100%-ában:	0 Mbit/s	0 Mbit/s

Key success factors of GSM

In USA

- No USA level decision on applied technology
- Concept: the competition is only way to select best technology
- AMPS, DAMPS, GSM, UMTS work parallel
- State level service licences

IN Europe

- Europe-wide specification and standardization in the first step
- Service licences and frequencies for standard systems only
- Free competition in the terminal market
- Regulated service market

GSM - The Wireless Evolution

- **The Wireless Evolution** is achieved through the GSM family of wireless technology platforms - today's GSM, GPRS, EDGE & 3GSM, 4GSM, 5GSM.

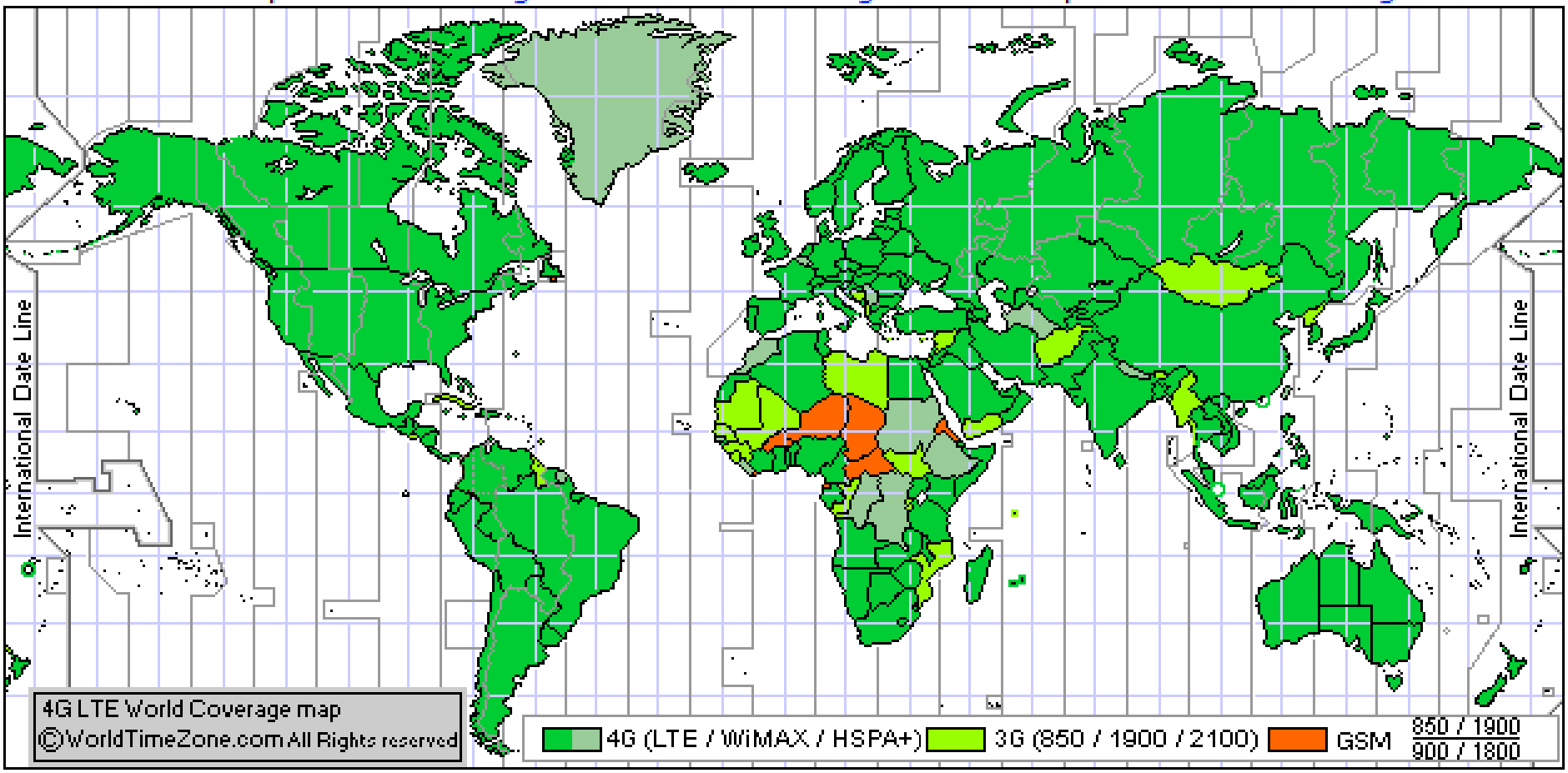
  Welcome to the wireless evolution where you will find a wealth of information on the GSM family of wireless communications. GSM is a living, evolving standard - growing and adapting to meet changing customer needs.

  It is the basis of a powerful family of platforms for the future - providing a direct link into next generation solutions including GPRS (General Packet Radio Services) EDGE (Enhanced Data for GSM Evolution) and 3GSM.
- LTE (Long Term Evolution)

- Long-Term Evolution, commonly marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements.
- The standard is developed by the 3GPP (3rd Generation Partnership Project)

4G LTE World Coverage Map - LTE, WiMAX, HSPA+, 3G, GSM Country List.

View Map of 5G field testing and trials World Coverage View Map of GSM World Coverage



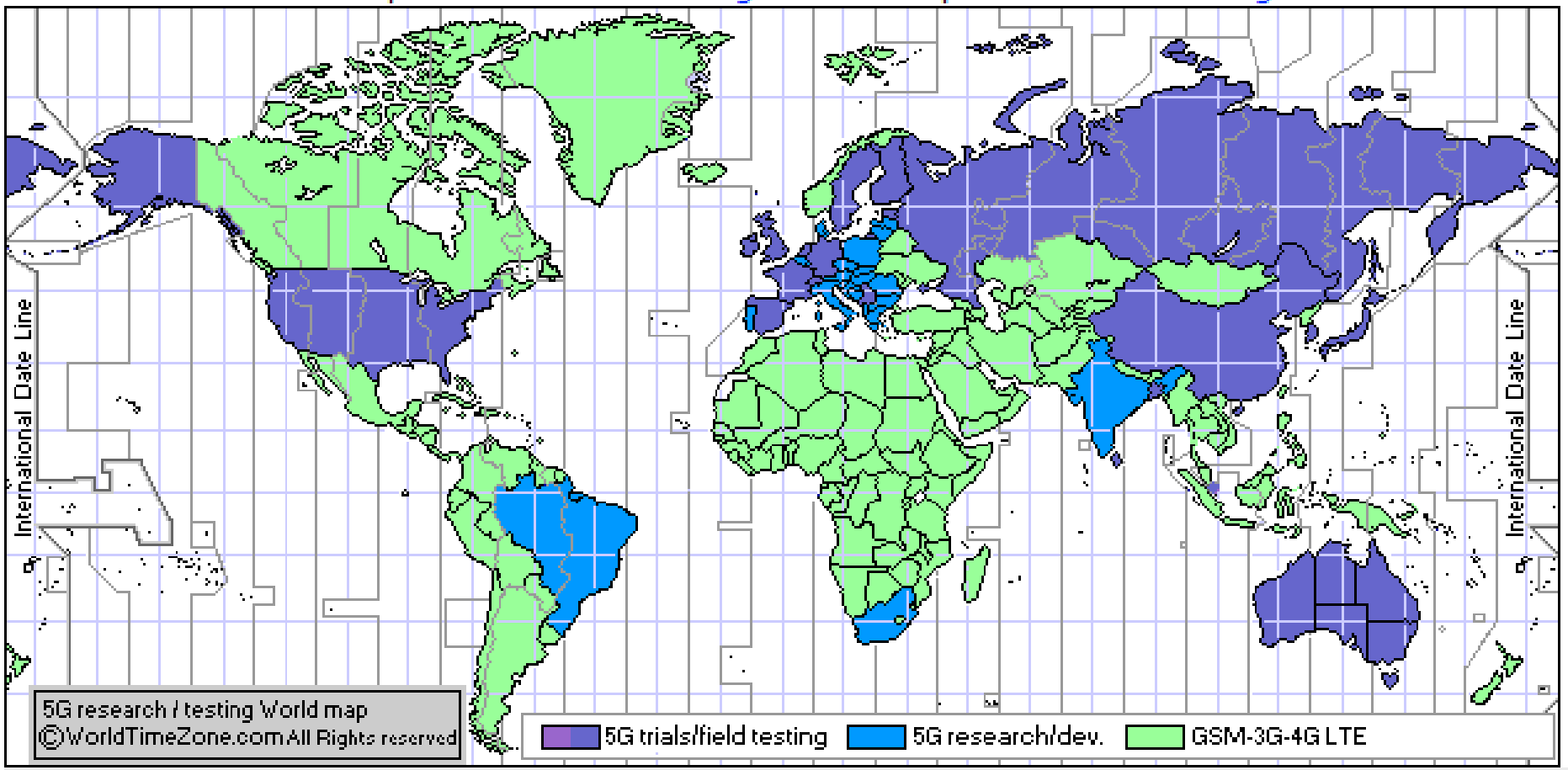
4G - marketing term (not all 4G networks are created equal). Major 4G standards:

- LTE (Long Term Evolution)- fastest of all 4G networks;
- HSPA+ (Evolved High-Speed Packet Access)- faster than 3G, however slower than LTE;
- WiMAX (Worldwide Interoperability for Microwave Access)- approximately the same speed as HSPA+
- LTE has been defined to accommodate paired spectrum FDD and unpaired spectrum TDD operations.

(In many countries, LTE, WiMAX, HSPA+, 3G UMTS, GSM networks coexist)

5G field testing, trials, research, development world coverage map - 5G country list

View Map of 4G LTE World Coverage View Map of GSM World Coverage



5G field testing / trials / research / development by country (2018)

LTE Features

LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. **The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.**

LTE Features

Peak download rates up to 299.6 Mbit/s and upload rates up to 75.4 Mbit/s depending on the user equipment category (with 4x4 antennas using 20 MHz of spectrum). Five different terminal classes have been defined from a voice centric class up to a high end terminal that supports the peak data rates. All terminals will be able to process 20 MHz bandwidth.

Low data transfer latencies (sub-5 ms latency for small IP packets in optimal conditions), lower latencies for handover and connection setup time than with previous radio access technologies.

Improved support for mobility, exemplified by support for terminals moving at up to 350 km/h (220 mph) or 500 km/h (310 mph) depending on the frequency band.

LTE Features

Support for both FDD and TDD communication systems as well as half-duplex FDD with the same radio access technology

Support for all frequency bands currently used by IMT systems by ITU-R.

Increased spectrum flexibility: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells are standardized. (W-CDMA requires 5 MHz slices, leading to some problems with roll-outs of the technology in countries where 5 MHz is a commonly allocated amount of spectrum, and is frequently already in use with legacy standards such as 2G GSM and cdmaOne.)

LTE Features

Support for cell sizes from tens of metres radius (femto and picocells) up to 100 km radius macrocells. In the lower frequency bands to be used in rural areas, 5 km is the optimal cell size, 30 km having reasonable performance, and up to 100 km cell sizes supported with acceptable performance. In city and urban areas, higher frequency bands (such as 2.6 GHz in EU) are used to support high speed mobile broadband. In this case, cell sizes may be 1 km or even less.

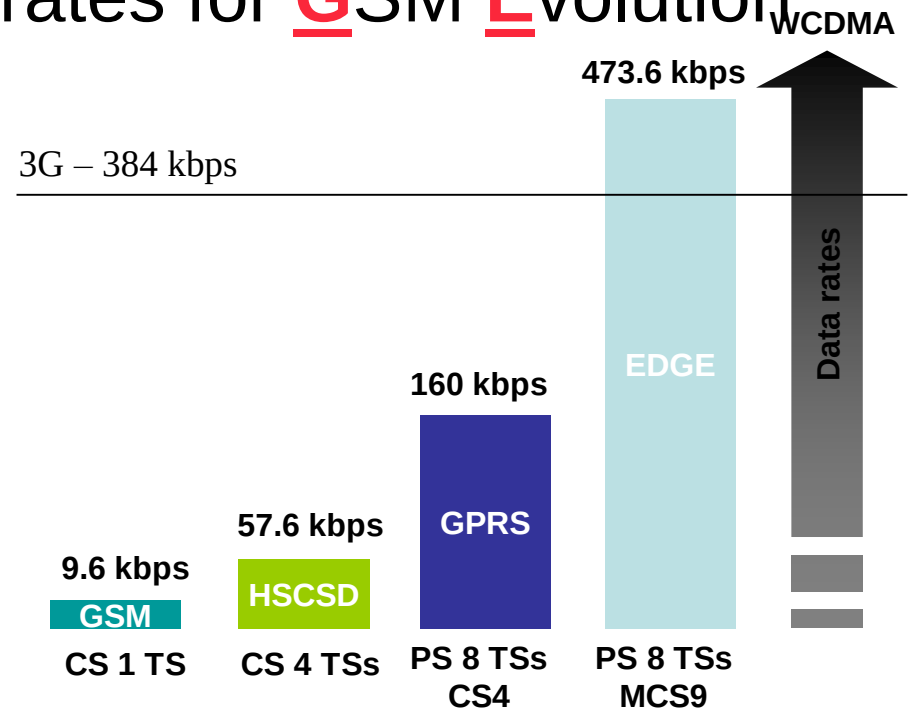
Supports at least 200 active data clients in every 5 MHz cell.

Simplified architecture: The network side of E-UTRAN is composed only of eNode Bs

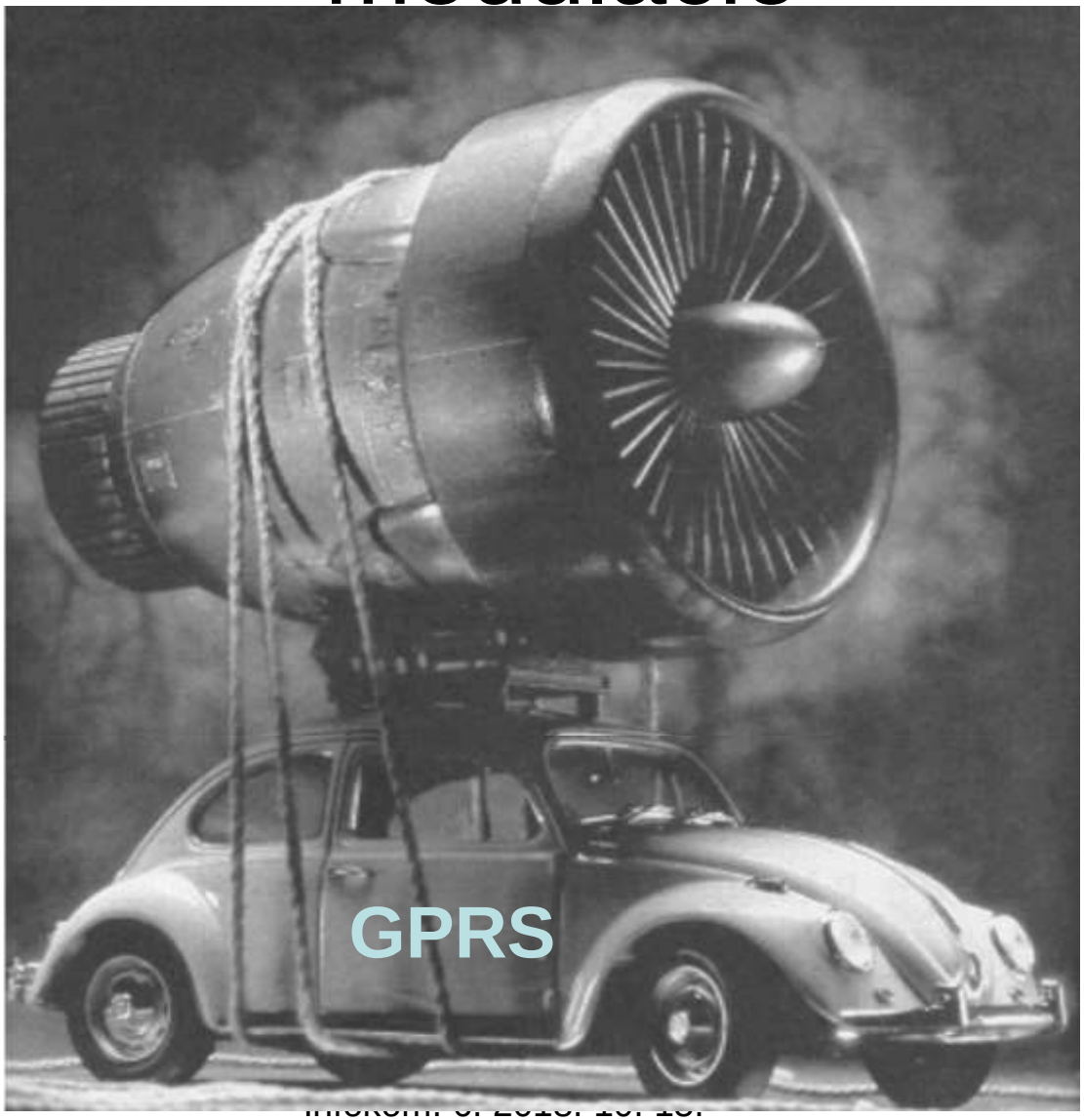
Az EDGE vajon mi?

- **GSM** = **G**lobal **S**ystem for **M**obile Communication
- **GPRS** = **G**eneral **P**acket **R**adio **S**ystem
- **EDGE** = **E**nhanced **D**ate rates for **G**SM **E**volution

- Harmadik generációs sebességek második generációs (GSM) spektrumban
- Az EDGE felgyorsítja a GSM-et…



EGPRS = GPRS + EDGE moduláció



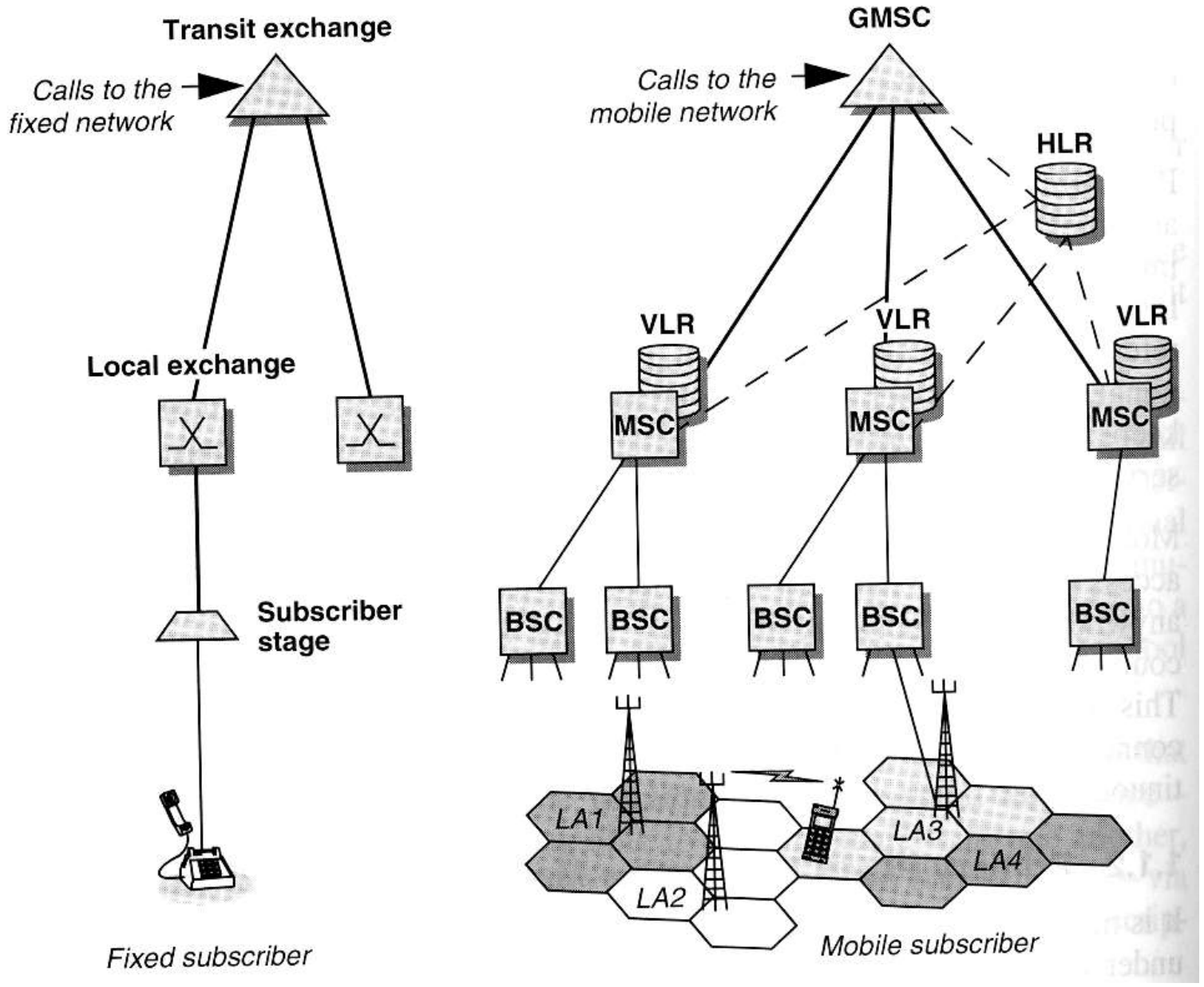
GSM specification items

- Voice oriented services
- Separation of terminal and subscription
- Europe-wide international roaming
- Low bit-rate speech coding
- High bandwidth utilisation
- Low power consumption in inactive mode
- Standards for system concept and air interface
- No direct call number information on air interface
- Encrypted speech coding on air interface
- Authentication process
- Handover up to 200km/h (car-phone or hand-held in train)
- Outdoor and indoor coverage

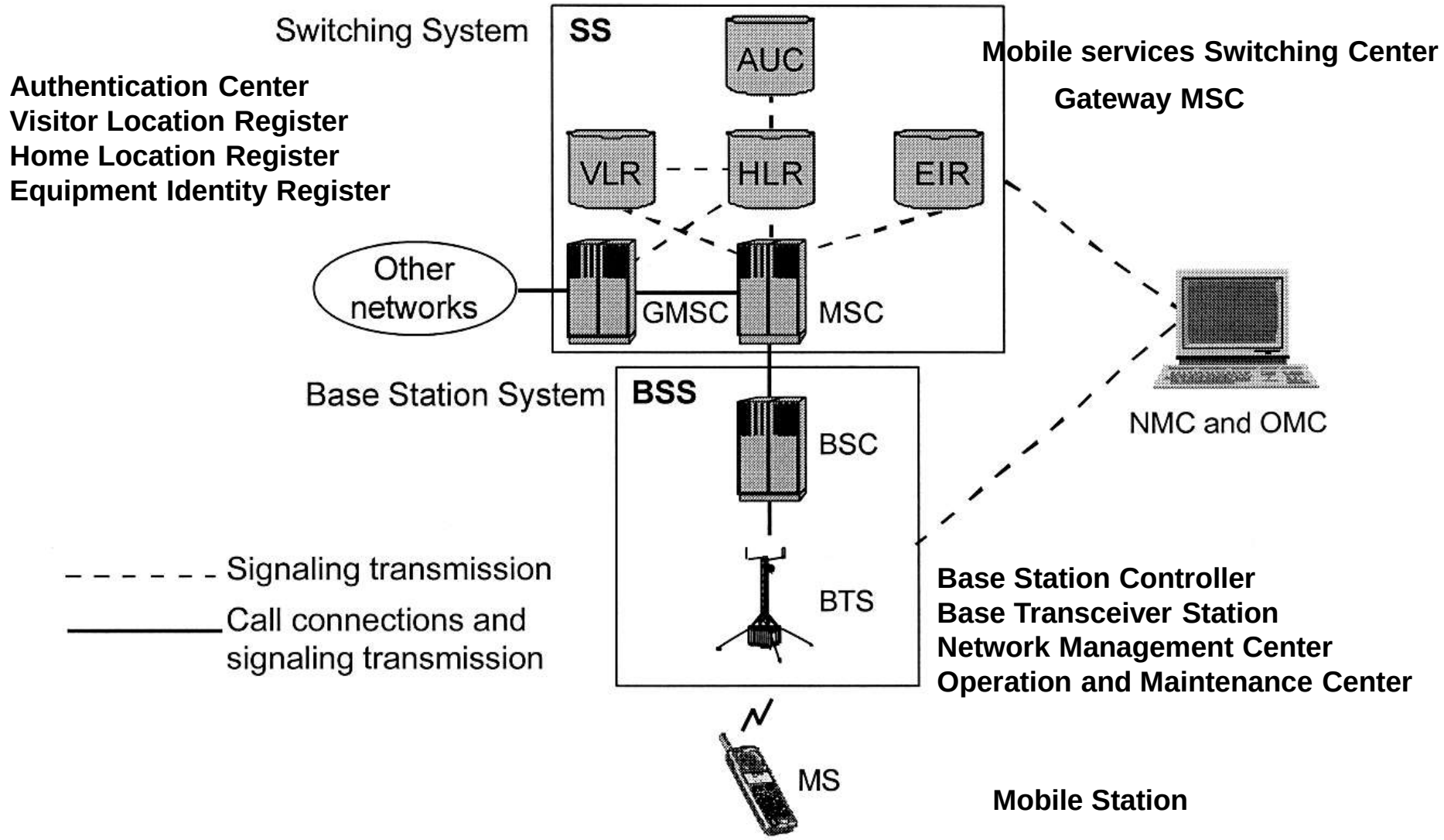
Basic figures of the GSM Standards

	GSM
Year introduced	1990
Access method	TDMA
Base station transmission band	935 to 960 MHz
Mobile station transmission band	890 to 915 MHz
Spacing between forward and reverse channels	45 MHz
Channel bandwidth	200 kHz
Number of duplex channels	125
Mobile unit maximum power	20 W
Users per channel	8
Modulation	GMSK
Carrier bit rate	270.8 kbps
Speech coder	RPE-LTP
Speech coding bit rate	13 kbps
Frame size	4.6 ms
Error control coding	Convolutional 1/2 rate

Comparison of wireline and wireless systems



GSM network components



Authentication Center
Visitor Location Register
Home Location Register
Equipment Identity Register

Mobile services Switching Center

Gateway MSC

Base Station Controller
Base Transceiver Station
Network Management Center
Operation and Maintenance Center

Mobile Station

Switching System Components

Home Location Register (HLR) Centralized network database for
- Subscriber identity
- Subscriber supplementary services
- Subscriber location information
- Subscriber authentication information

Visitor Location Register (VLR)
- Information about subscribers located in an MSC service area (a copy of HLR information)

Roaming into a new MSC service area the actual MSC request information from the subscriber’s HLR.

The AUC is to authenticate subscribers attempting to use a network

Equipment Identity Register (EIR)
- Database to block calls from stolen, unauthorized or defective MSs.

Base Station System (BSS) components

- Base Station Controller (BSC)
  - Manages all the radio related functions of the network
  - MS handover
  - Radio channel assignment
  - collection of cell configuration data
  - Controlled by MSC
- Base Transceiver Station (BTS)
  - control the radio interface to the MS
  - Comprises transceivers and antennas
  - Controlled by BSC

Network Monitoring Centers

Operation and Maintenance Center (OMC)

- a computer system
- connected to MSCs and BSCs via data links
- presents information on the status of the network
- Can control system parameters
- For short term, regional issues

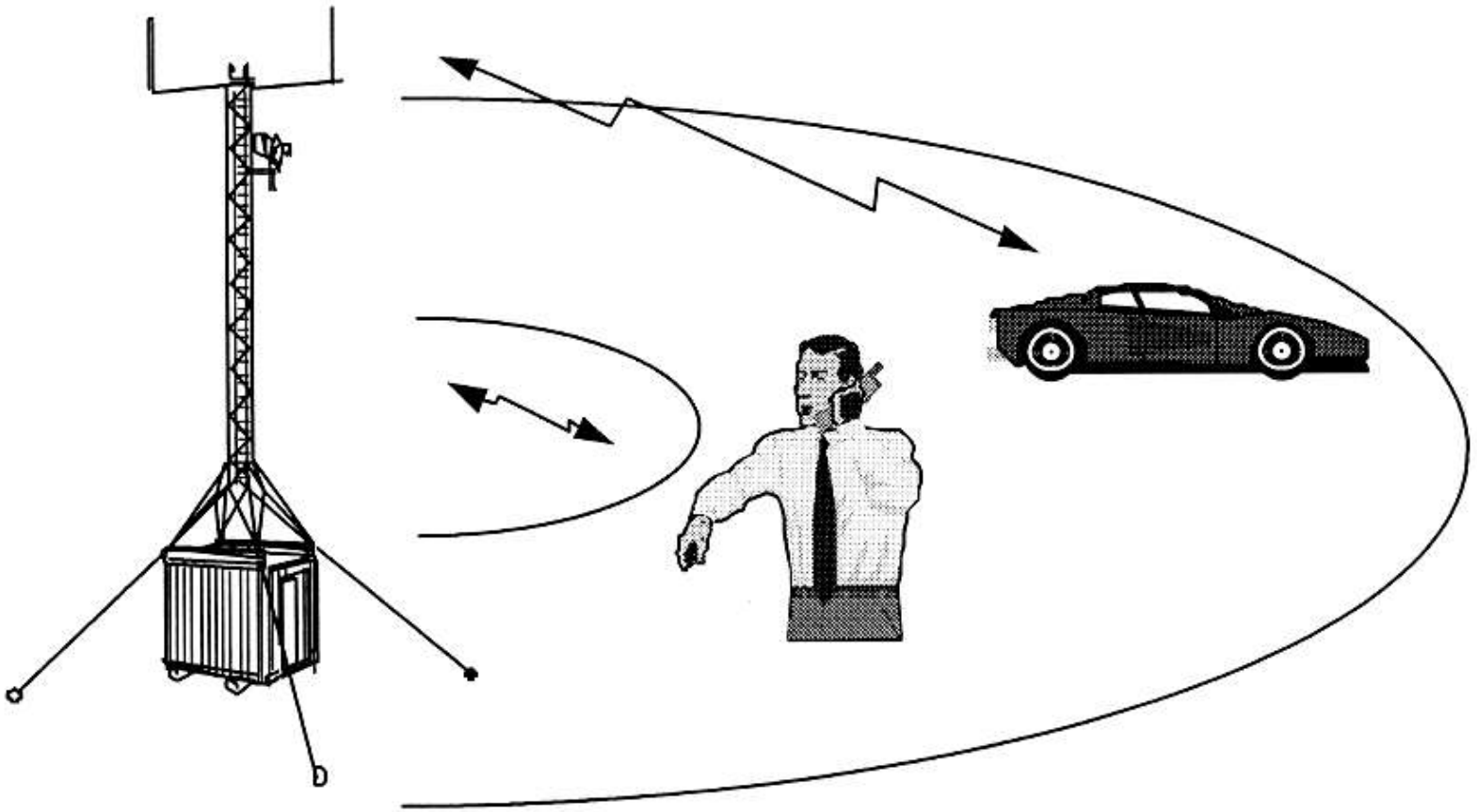
Network Management Center (NMC)

- Centralized Control of a network
- For long term system wide issues

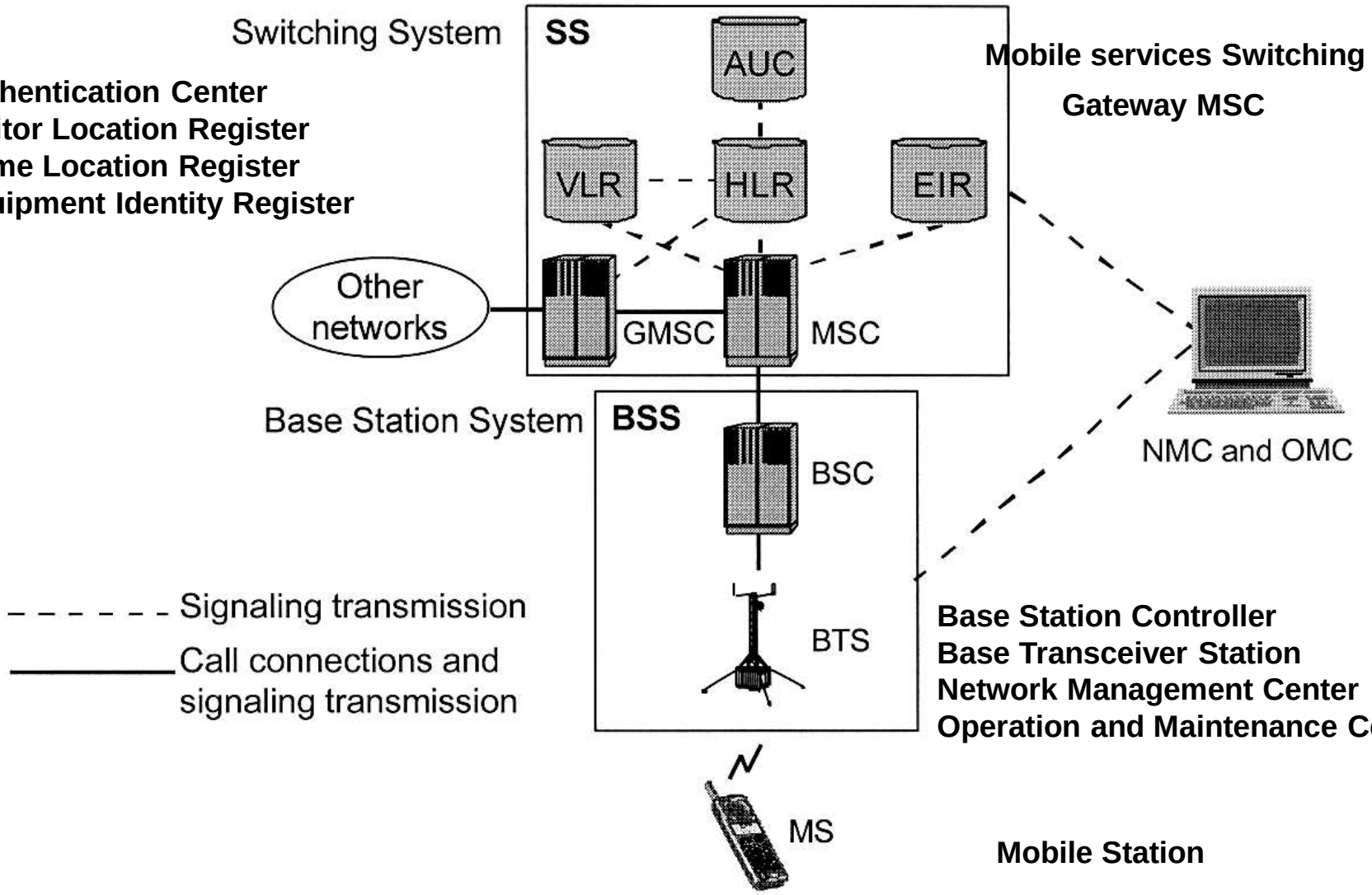
Mobile Station (MS)

- Used by mobile subscriber to communicate with the network
- Consist of mobile terminal and Subscriber Identity Module (SIM)
- Subscription is separated from the mobile terminal
- Subscription information is stored in a „smart card”
- Hand-held MS, Car-installed MS

Ranges for different type of MSs



GSM network components



Authentication Center
Visitor Location Register
Home Location Register
Equipment Identity Register

Mobile services Switching Center

Gateway MSC

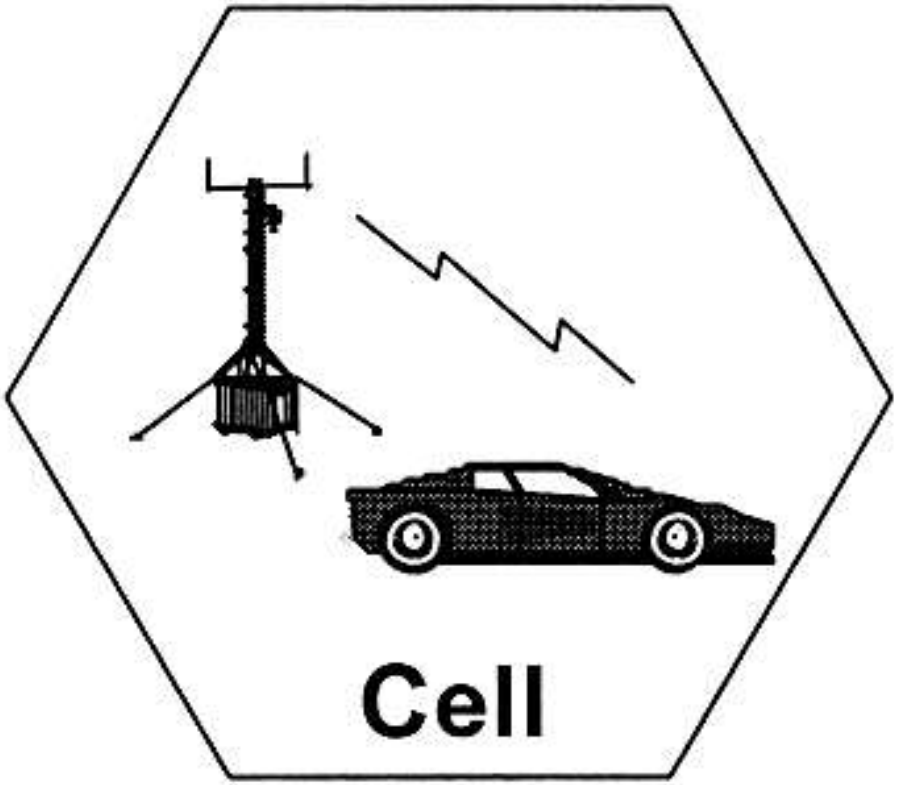
Base Station Controller
Base Transceiver Station
Network Management Center
Operation and Maintenance Center

Mobile Station

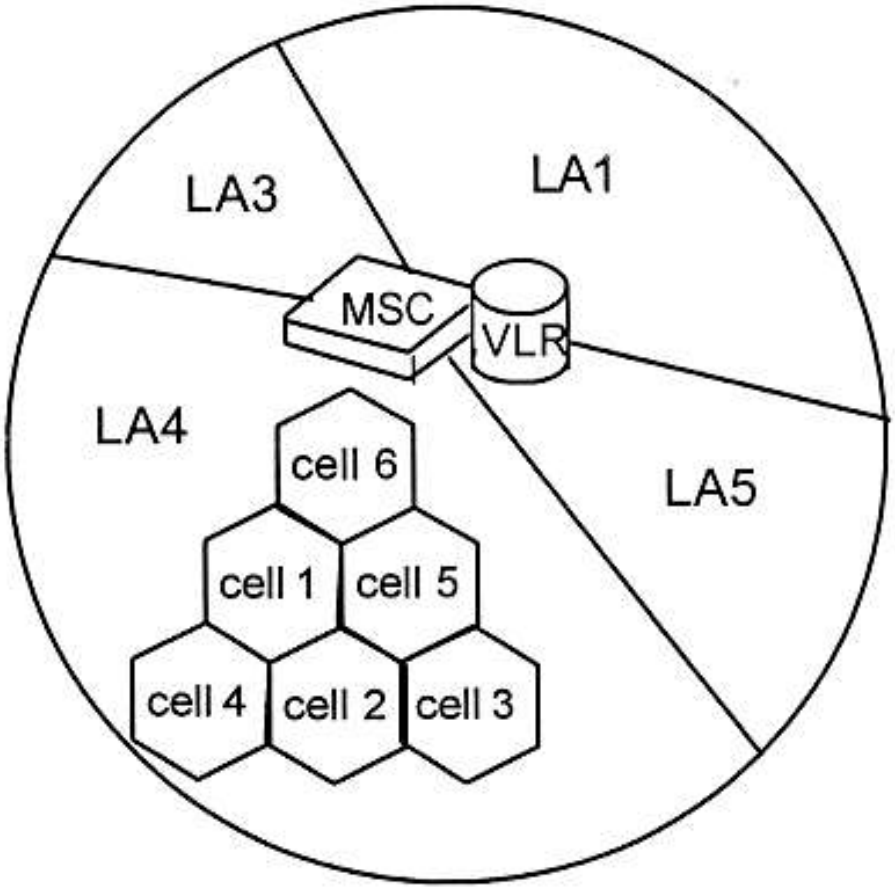
GSM Geographic Network Structure

- CELL: area of radio coverage by one BS antenna system, assigned to specific number (Cell Global Identity)
- Location Area (LA): Group of cells, the identity of LA stored in VLR
- PLMN Service area: set of cells served by one network operator (e.g. Telenor Hungary)
- GSM Service Area: geographic area in which a subscriber can gain access to a GSM network (e.g. Europe)

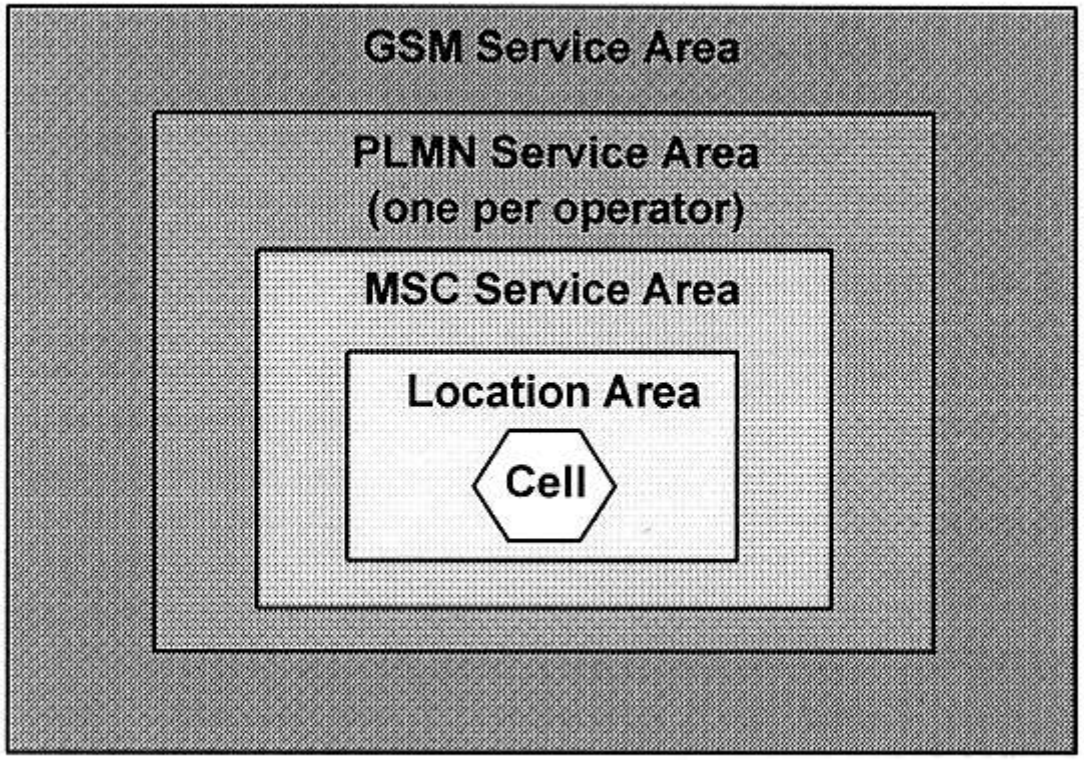
Cell



Location Area (LA)



GSM Geographic Network Structure



MS states

- Idle: the MS is ON but a call is not in progress
- Active: The MS is ON and a call is in progress
- Detached: The MS is OFF

Idle key terms

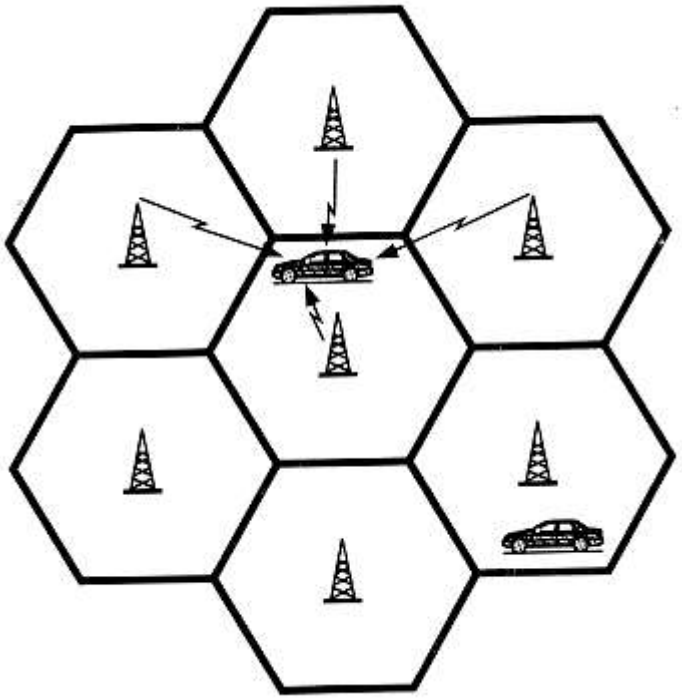
- Registration: MS informs a network that it is attached
- Roaming: MS moves around the network in idle mode
- International Roaming: MS moves into a network which is not its home network
- Location Updating: MS inform the network when enters in new LA
- Locating: BSC function to suggest connection to another cell based on MS measurement reports
- Paging: The network tries to contact an MS by broadcasting message containing MS identity

Active key terms

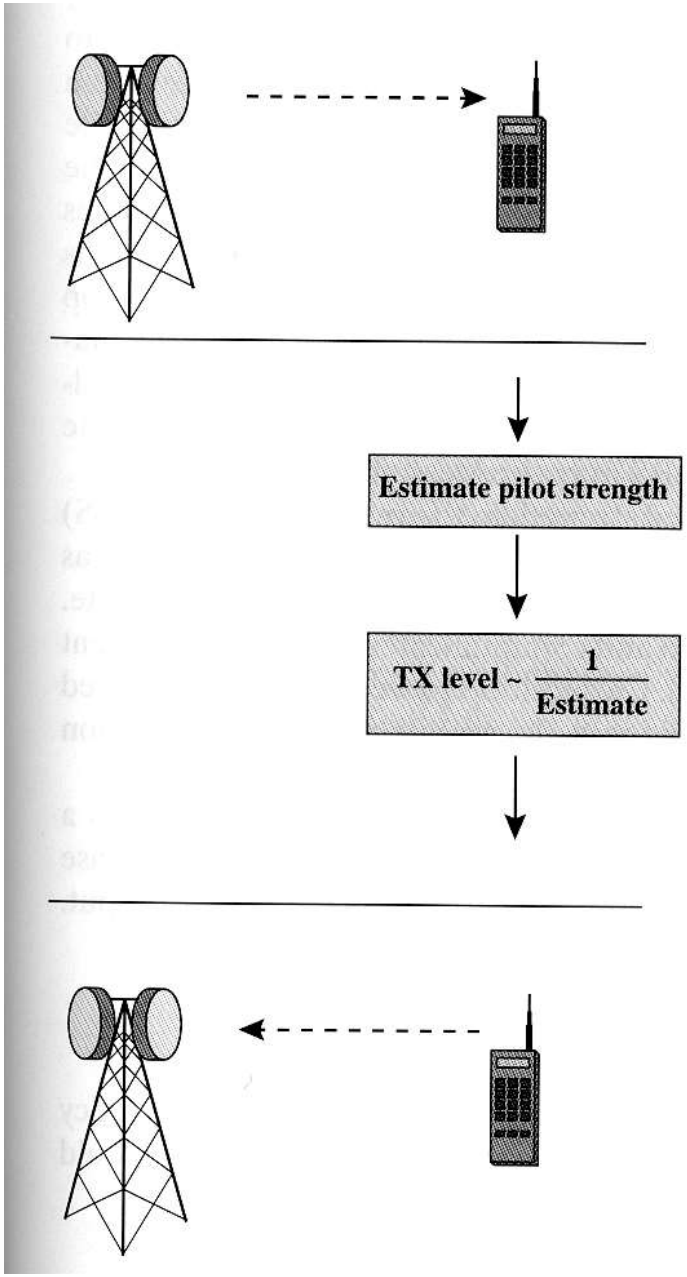
- Handover: Process, where a call is switched from one physical channel to another, while MS moves around

MS registration

- MS power ON
- MS scans for control channel frequencies
- MS measures signal levels and records it
- MS tunes to the strongest frequency
- MS register to the network
- Network update the MS status to idle
- Network store location information



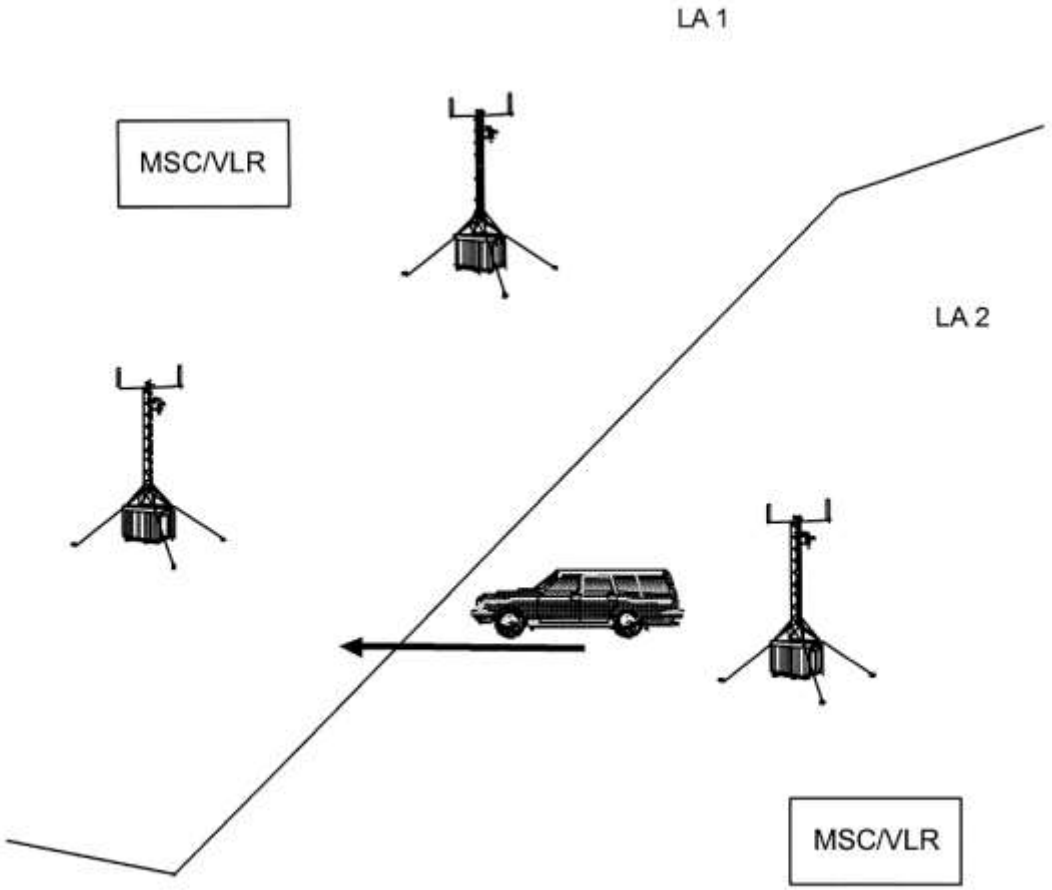
(c) Monitor for strongest sig



MS sending power control

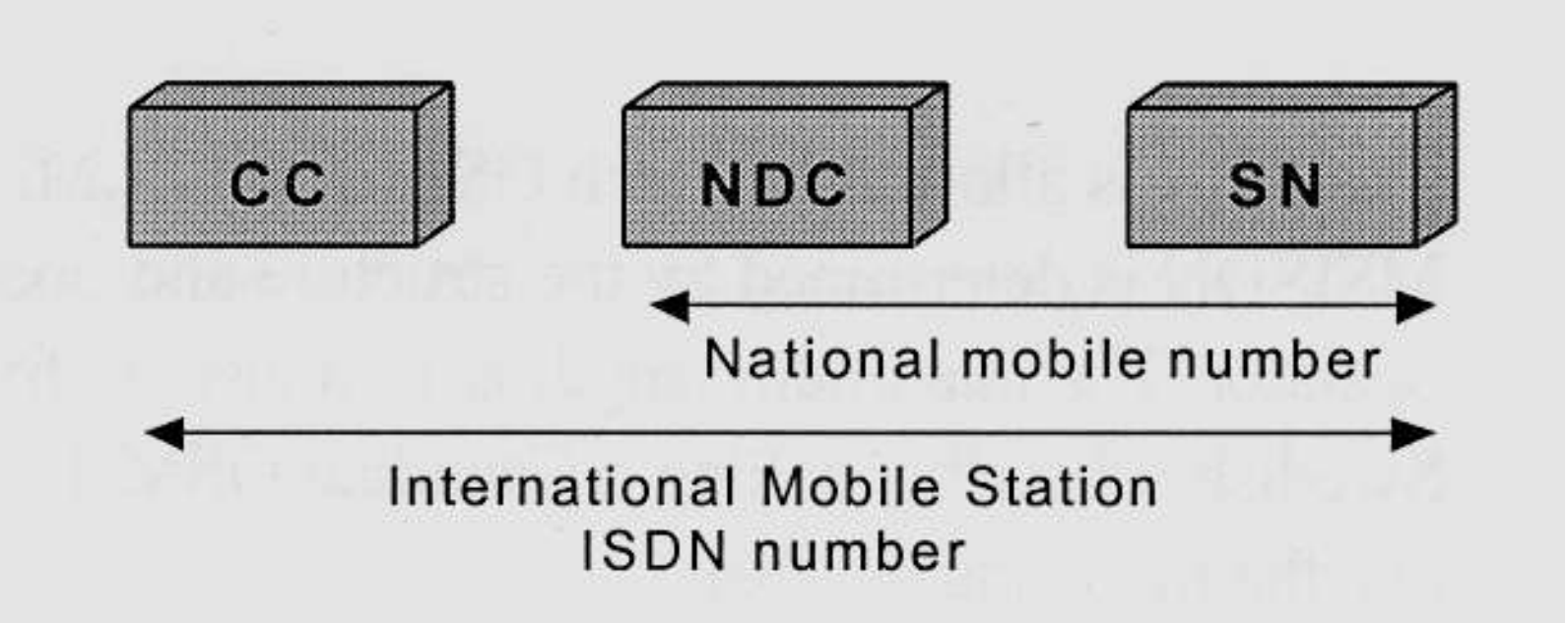
MS roaming

The idle MS moves thorough the network,
scan the control channels,
tune to the strongest channel,
in new LA inform the network of its new location



The MSISDN

CC Country Code (36 for Hungary)
NDC National Destination Code (20 for TELENOR HUNGARY)
SN Subscriber Number (e.g. 9888444)

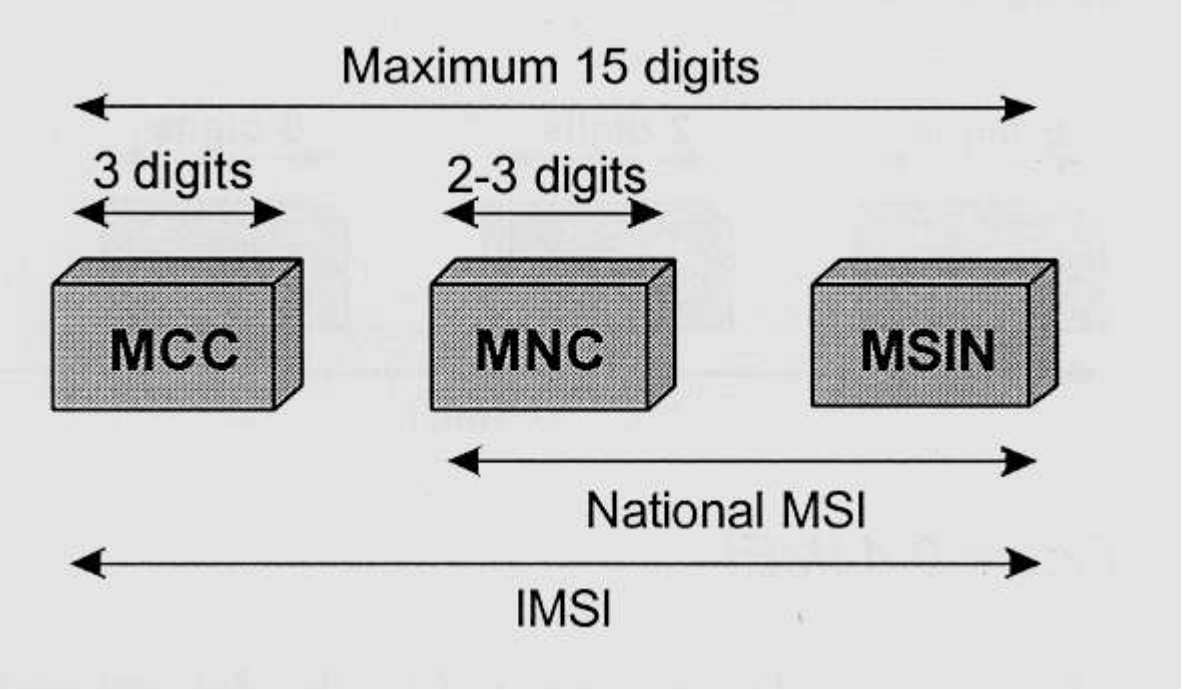


IMSI -TMSI

MCC Mobile Country Code
MNC Mobile Network Code
MSIN Mobile Station Identification Number

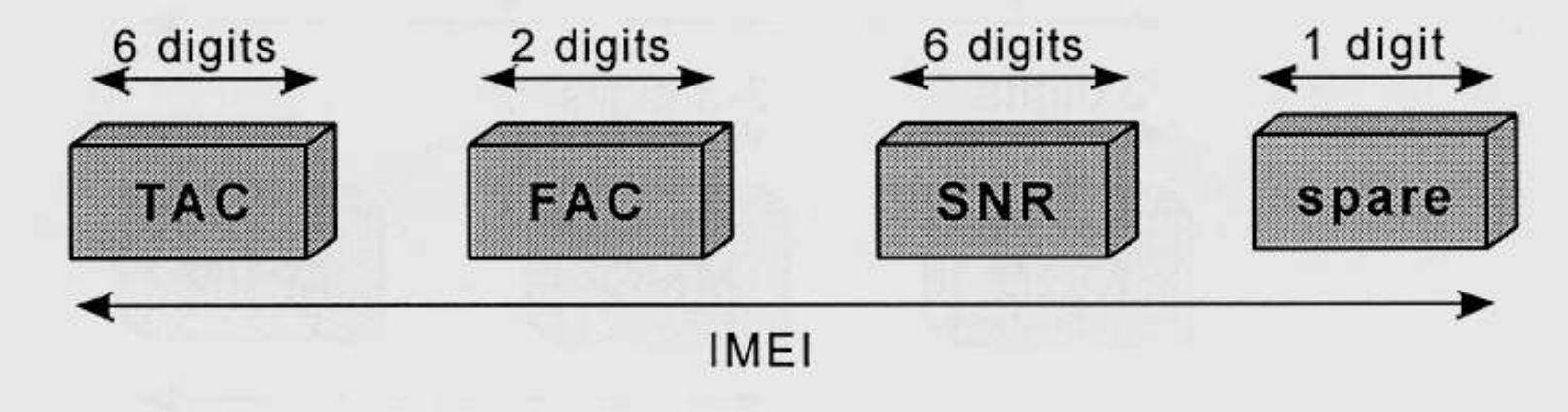
Stored in SIM, HLR, VLR

Temporary IMSI number
Known to MS at registration
Local significance
Within MSC
8 digits



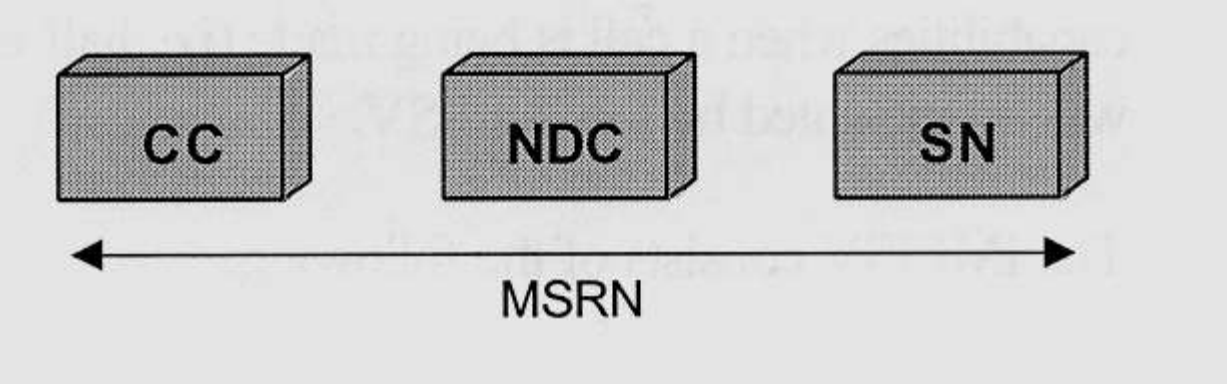
IMEI

TAC Type Approval Code
FAC Final Assembly Code
SNR Serial Number



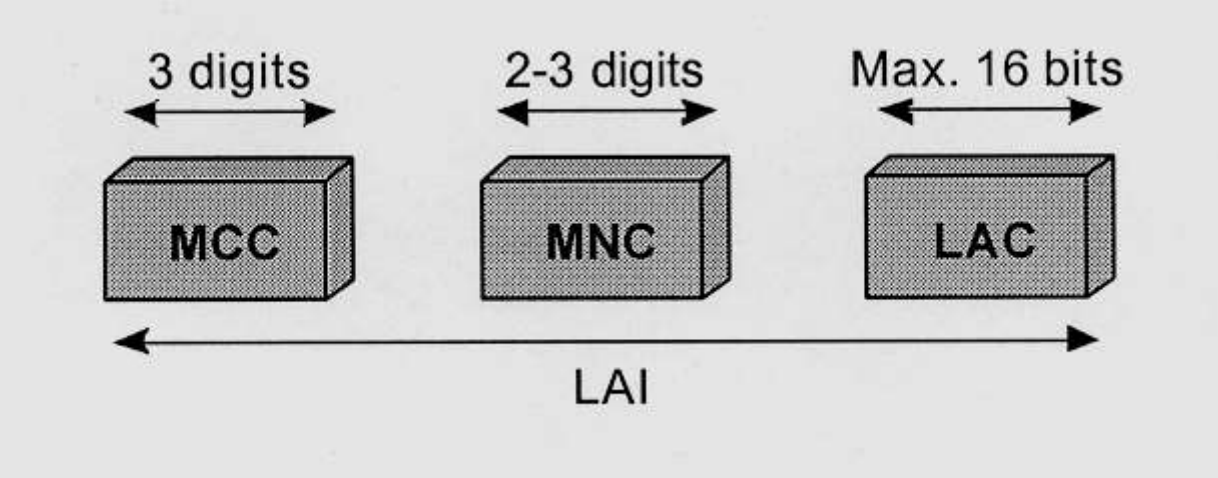
Mobile Station Roaming Number (MSRN)

CC Country Code (36 for Hungary)
NDC National Destination Code (20 for TELENOR HUNGARY)
SN Service Node



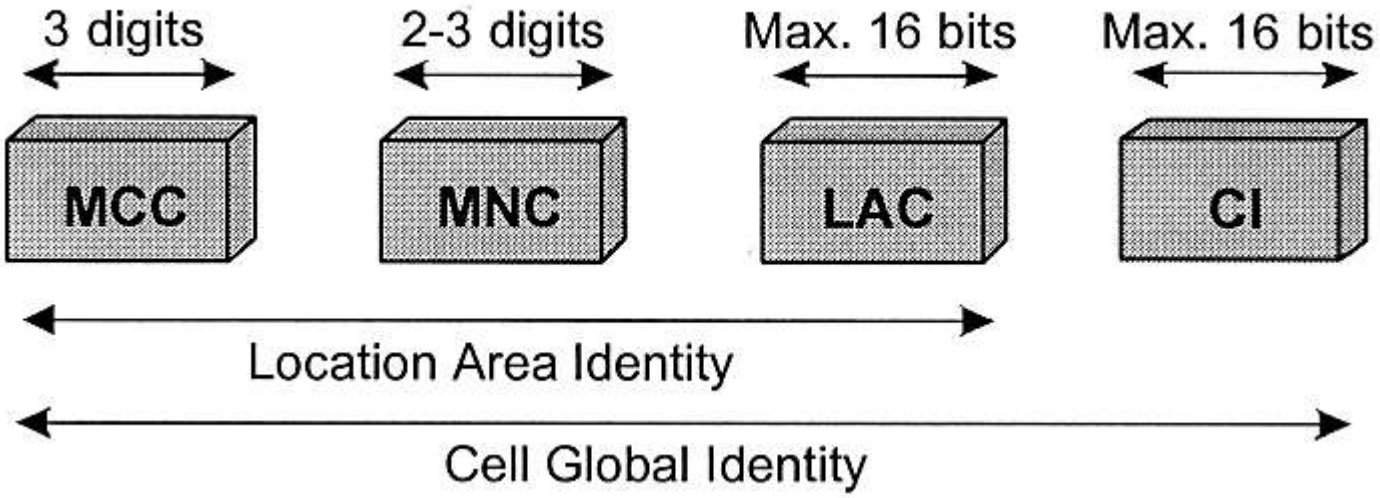
Local Area Identity (LAI)

LAC Location Area Code



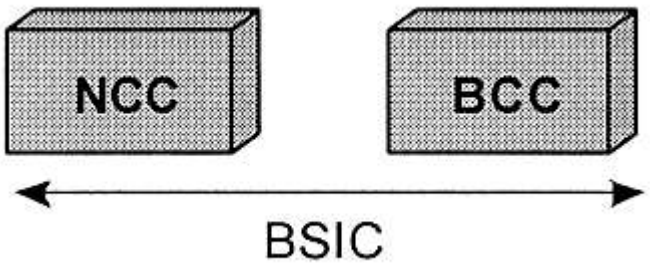
Cell Global Identity (CGI)

CI Cell Identity

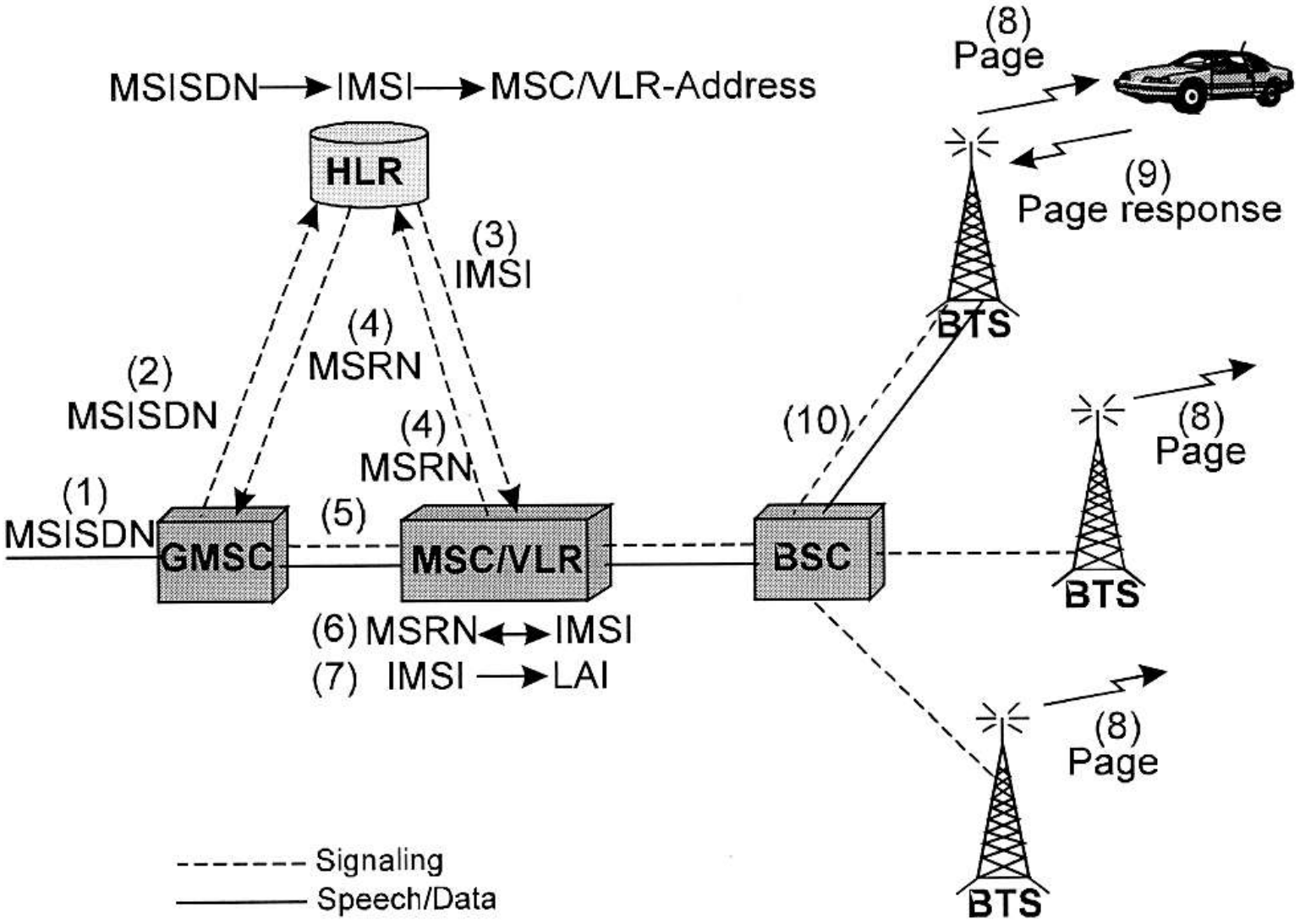


Network Station Identity Code (BSIC)

NCC Network Colour Code
BCC Base Station Colour Code



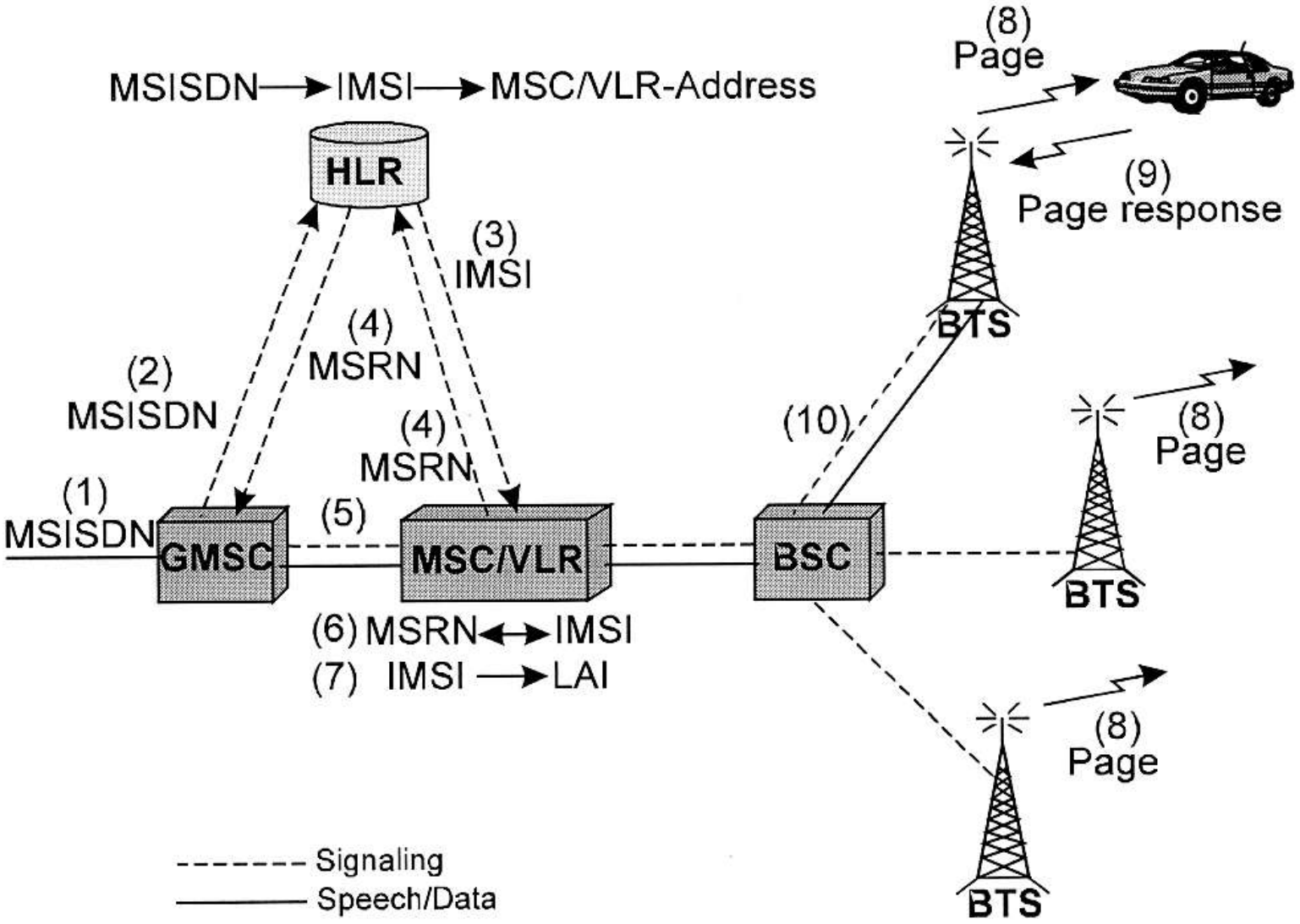
Call to an MS


MSISDN → IMSI → MSC/VLR-Address
HLR
(1) MSISDN
(2) MSISDN
(3) IMSI
(4) MSRN
(4) MSRN
(5)
GMSC
MSC/VLR
BSC
(6) MSRN ↔ IMSI
(7) IMSI → LAI
(8) Page
(9) Page response
(10)
BTS
(8) Page
BTS
(8) Page
BTS
Signaling
Speech/Data

Call to an MS

1. Call entering to GSM network is routed to the nearest GMSC
2. The GSM analyse the MSISDN to find the HLR (subscriber registered in) The MSC/VLR address is stored in HLR, the IMSI is stored in HLR
3. The HLR send request to an MSRN to the MSC/VLR included in the message the IMSI
4. The MSRN is returned via HLR to the GMSC

Call to an MS


MSISDN → IMSI → MSC/VLR-Address
HLR
(1) MSISDN
(2) MSISDN
(3) IMSI
(4) MSRN
(4) MSRN
(5)
GMSC
MSC/VLR
BSC
(6) MSRN ↔ IMSI
(7) IMSI → LAI
(8) Page
(9) Page response
(10)
BTS
(8) Page
BTS
(8) Page
BTS
Signaling
Speech/Data

Call to an MS

5 The GMSC routes the call to the MSC/VLR by MSRN

6 The MSC/VLR retrieve the Ms's IMSI

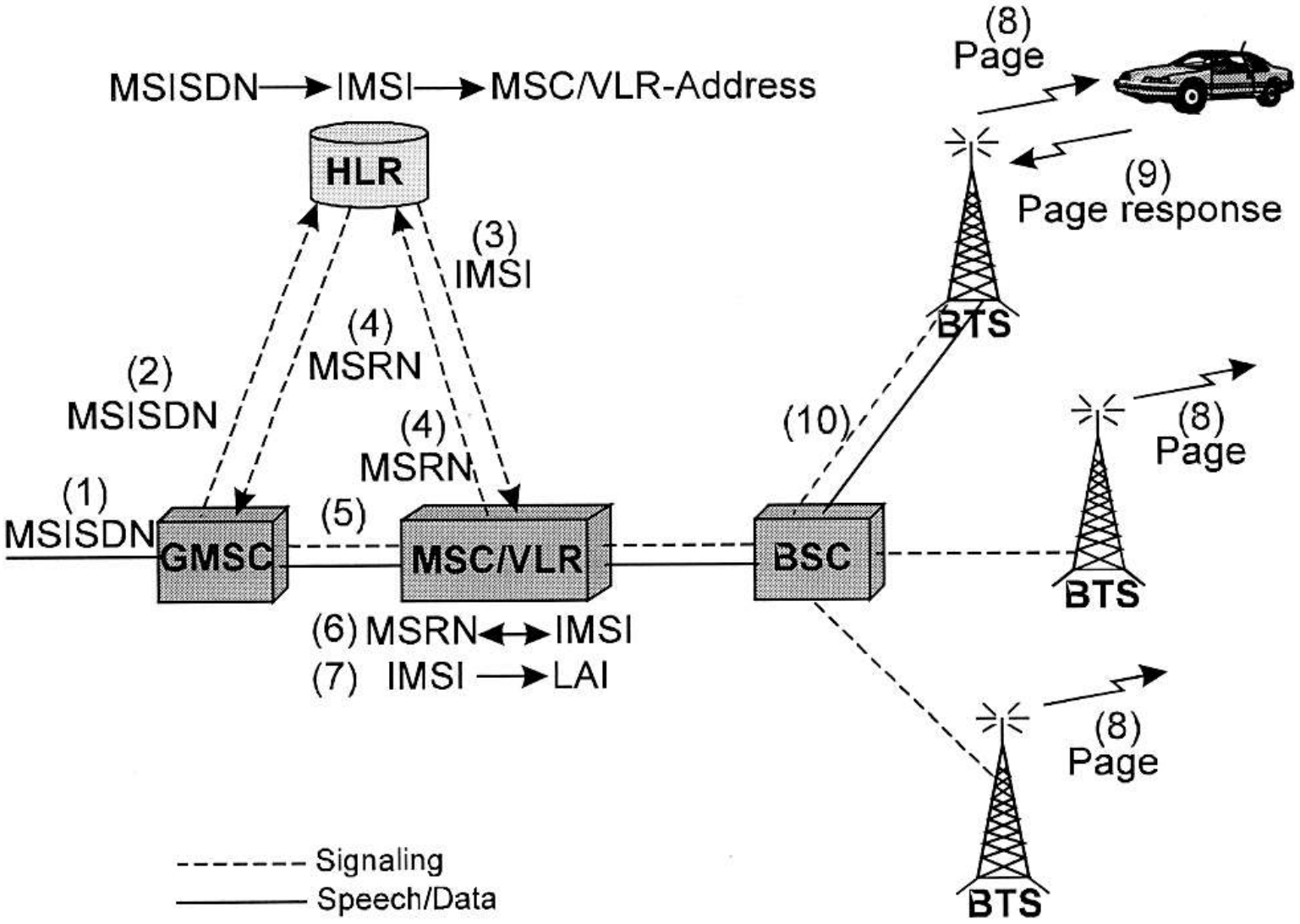
7 Using IMSI MSC identifies LA

8 The MS is paged in cells in the LA

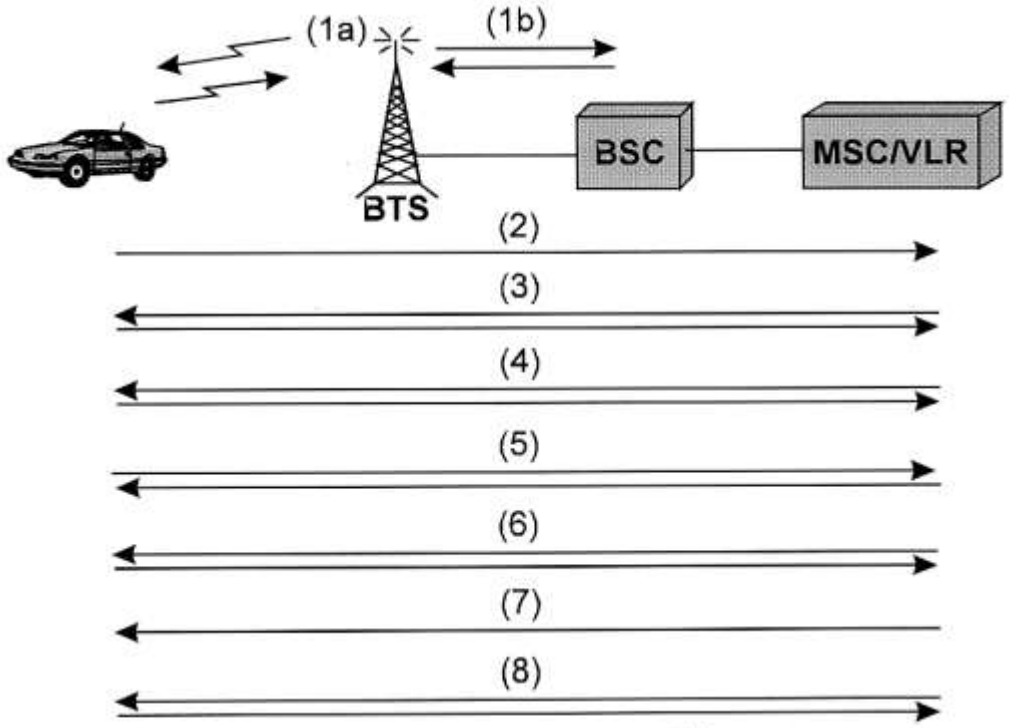
9 MS responds, authentication, cipher mode setting, IMEI check are carried out

10 Traffic channel connected from MSC to BSC and the BTS

Call to an MS


MSISDN → IMSI → MSC/VLR-Address
HLR
(1) MSISDN
(2) MSISDN
(3) IMSI
(4) MSRN
(4) MSRN
(5)
GMSC
MSC/VLR
BSC
(6) MSRN ↔ IMSI
(7) IMSI → LAI
(8) Page
(9) Page response
(10)
BTS
(8) Page
BTS
(8) Page
BTS
Signaling
Speech/Data

Call from MS

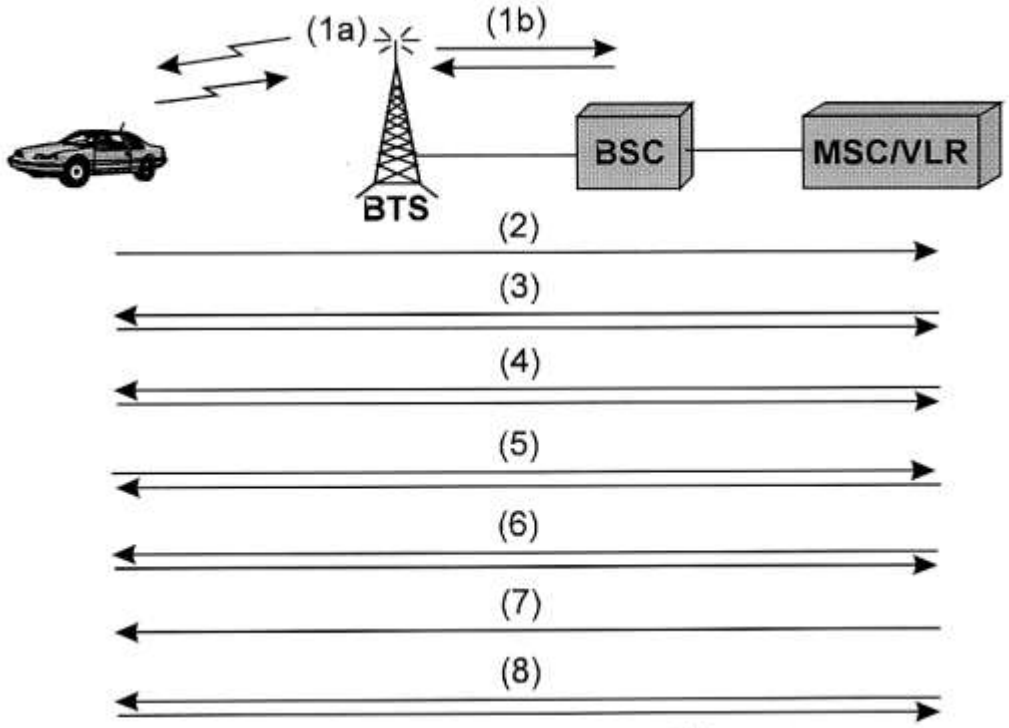


(1a), (1b)	RR connection establishment
(2)	Service indication
(3)	Authentication
(4)	Ciphering mode setting
(5)	Call initiation
(6)	TCH assignment
(7)	Call confirmation
(8)	Call accepted

Call from MS

1. Call start with a signalling channel using RACH (Random Access Channel)
2. MS indicates request, IMSI is analyzed, MS marked busy in The VLR
3. Authentication is performed by MSC
4. Ciphering is initiated, IMEI validated
5. MSC receives a setup message from MS (including B number)

Call from MS



(1a), (1b)	RR connection establishment
(2)	Service indication
(3)	Authentication
(4)	Ciphering mode setting
(5)	Call initiation
(6)	TCH assignment
(7)	Call confirmation
(8)	Call accepted

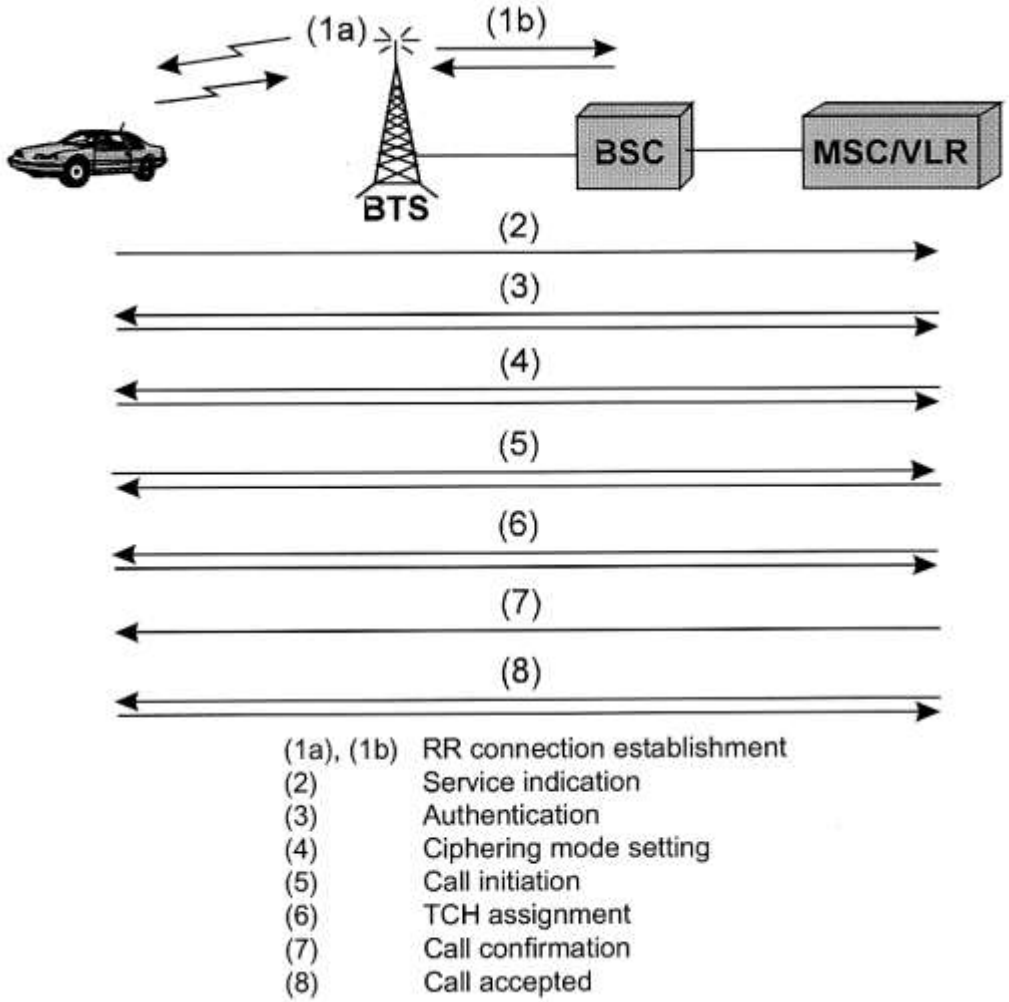
Call from MS

6 Link established between MSC and BSC to assign traffic channel

7 call confirmation

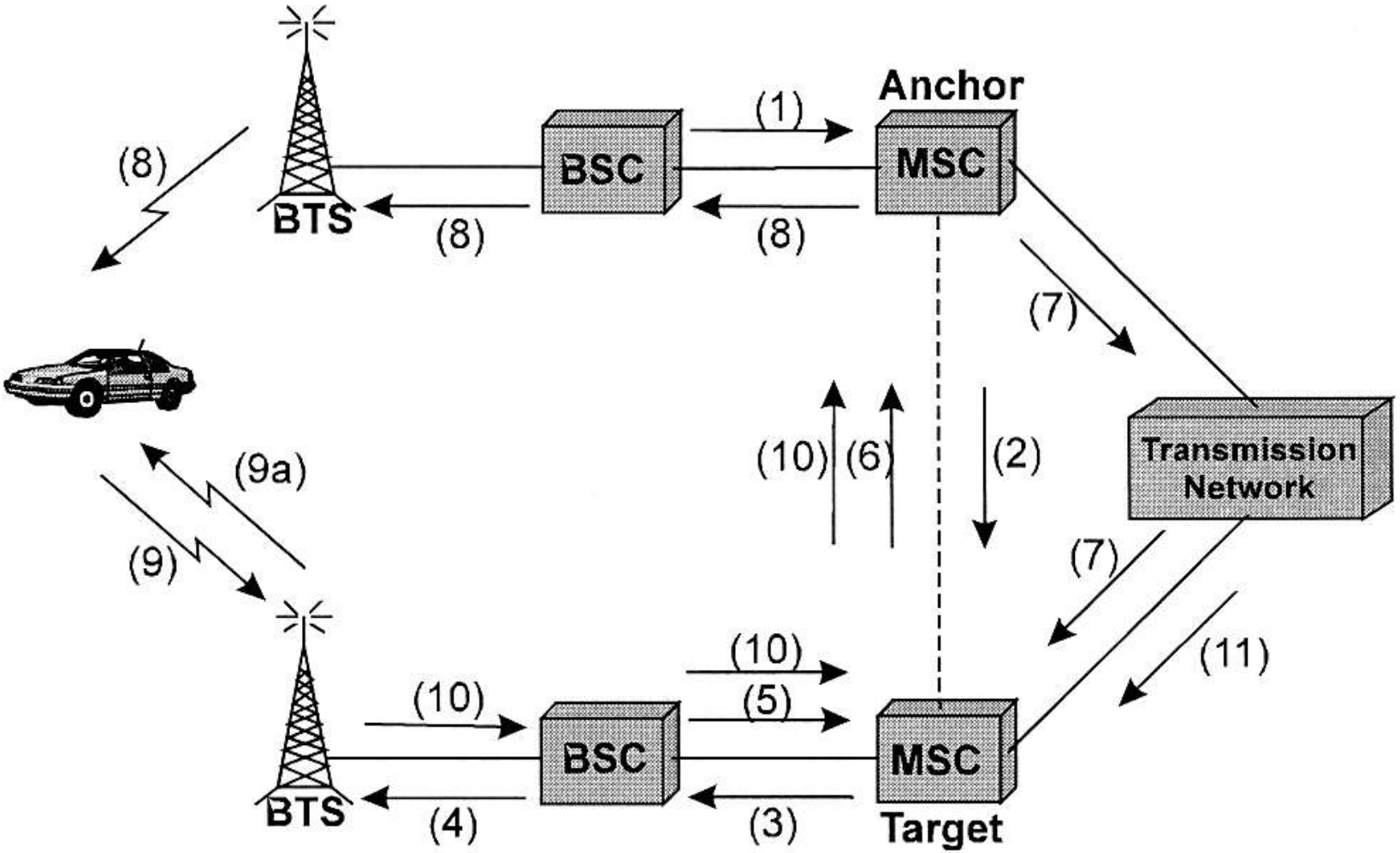
8 Call accepted

Call from MS



(1a), (1b)	RR connection establishment
(2)	Service indication
(3)	Authentication
(4)	Ciphering mode setting
(5)	Call initiation
(6)	TCH assignment
(7)	Call confirmation
(8)	Call accepted

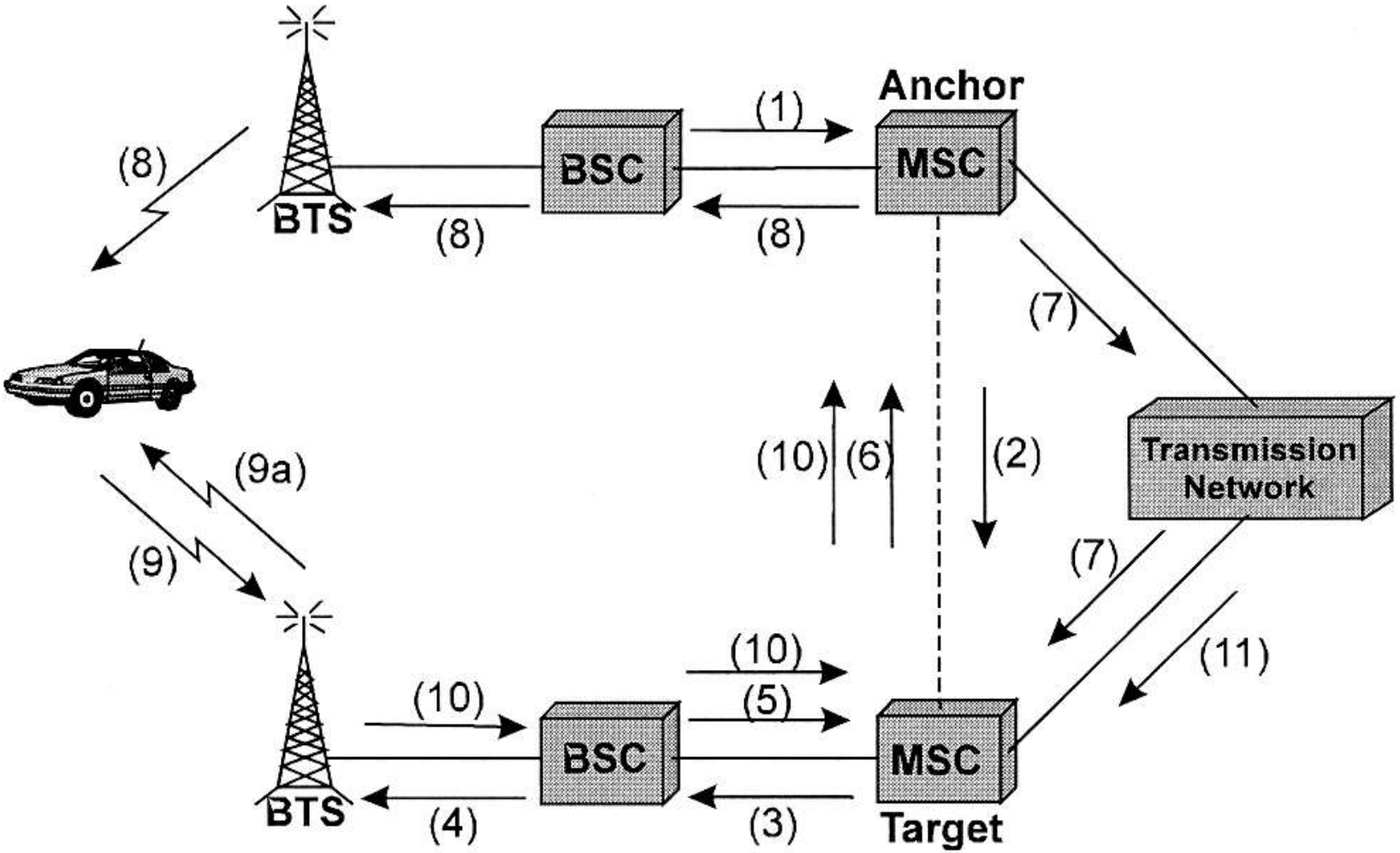
Basic Handover



Basic Handover

1. BSC send handover-required message to the MSC
2. The MSC ask the target MSC to assist. The Target MSC allocates a handover number that reroutes the call.
3. A handover request is sent down to the new BSC
4. The BSC tells the new BTS to activate a TCH
5. The MSC receives the information about the new Traffic CHannel

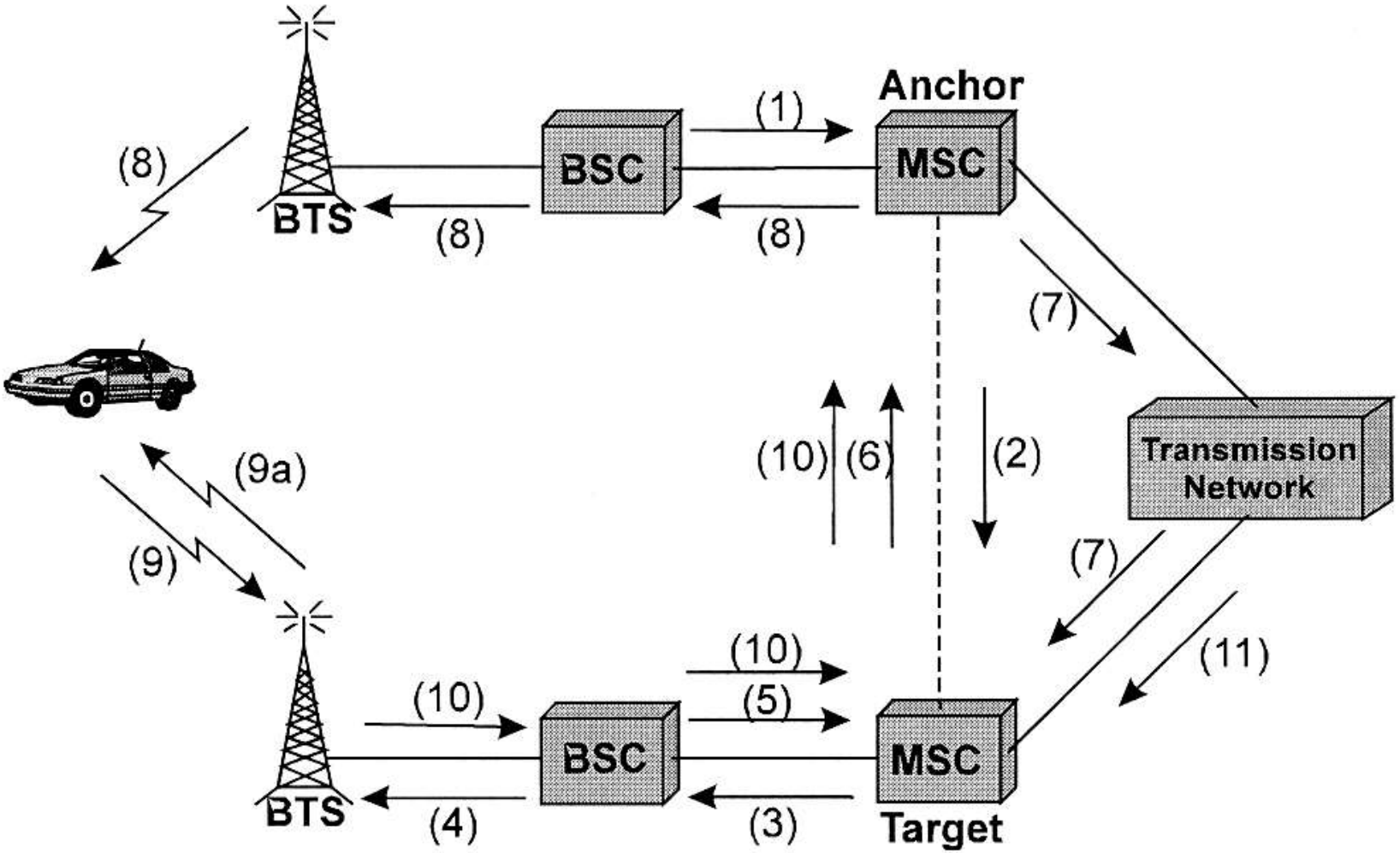
Basic Handover



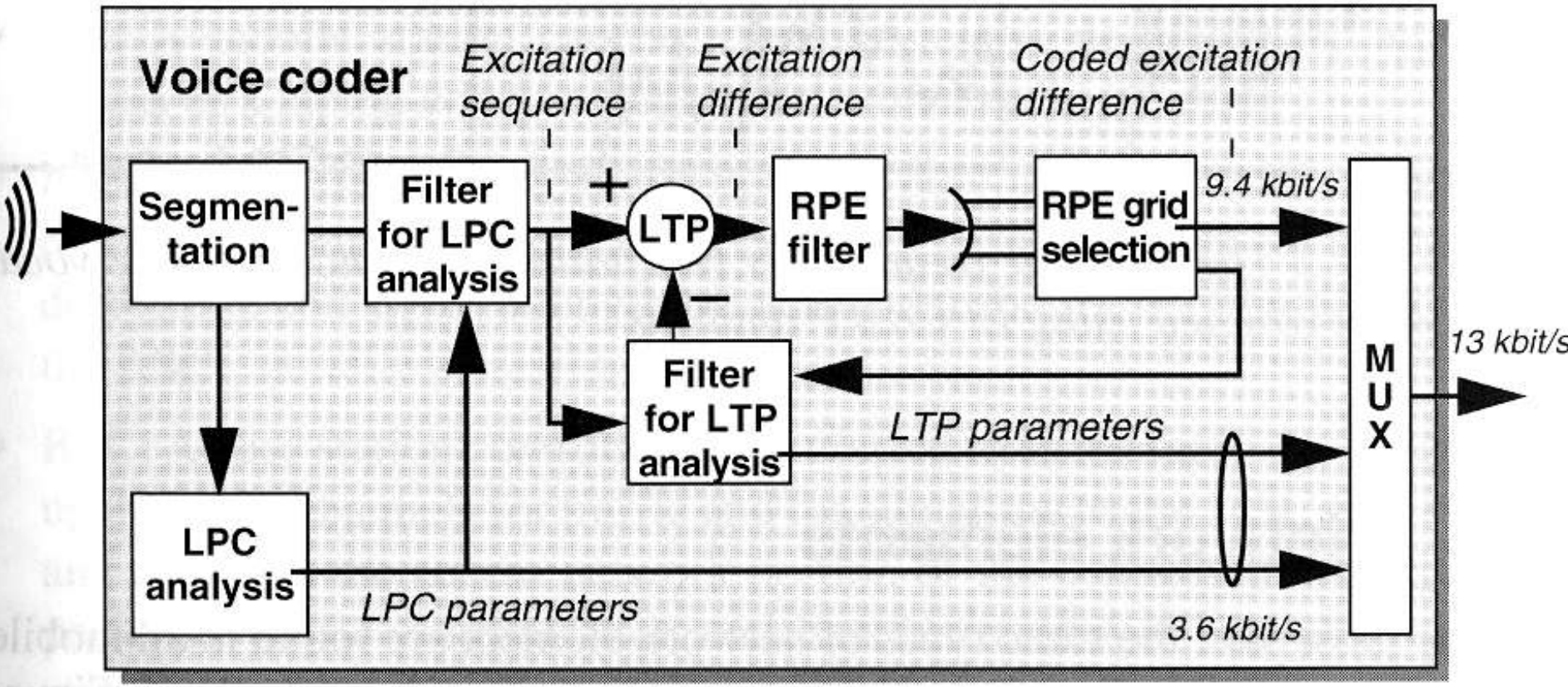
Basic Handover

6. The MSC passes info on new TCH from new BSC
7. A speech path to the new MSC is set up.
8. A handover command goes to the MS with frequency and time slot data in the new cell.
9. The MS sends handover burst on the new TCH
10. The target MSC is informed that the handover successful
11. A new path in the Group Switch is set up.

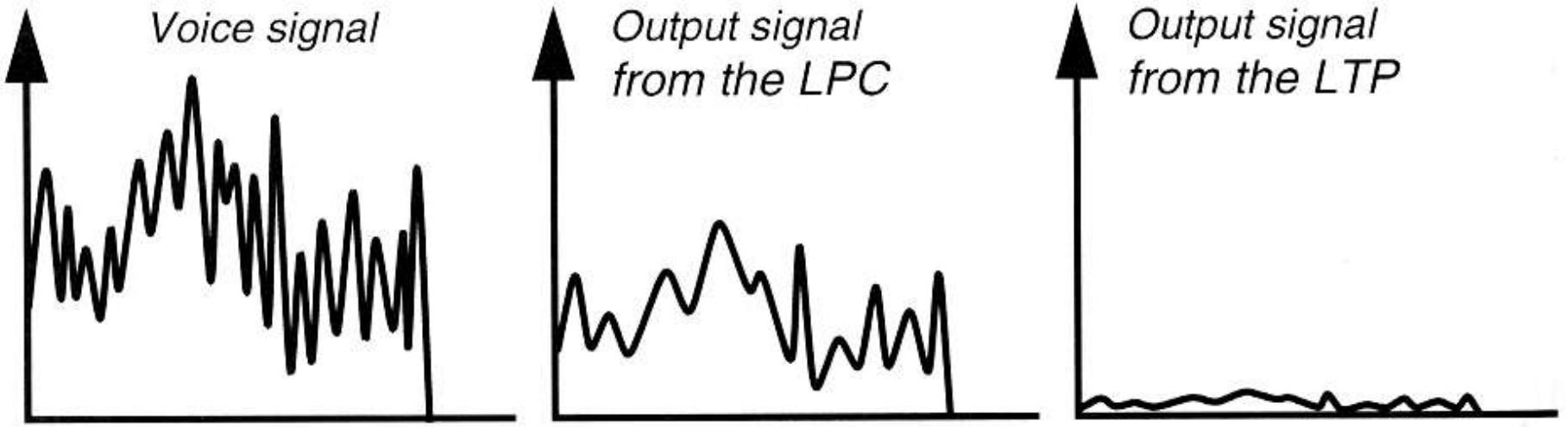
Basic Handover



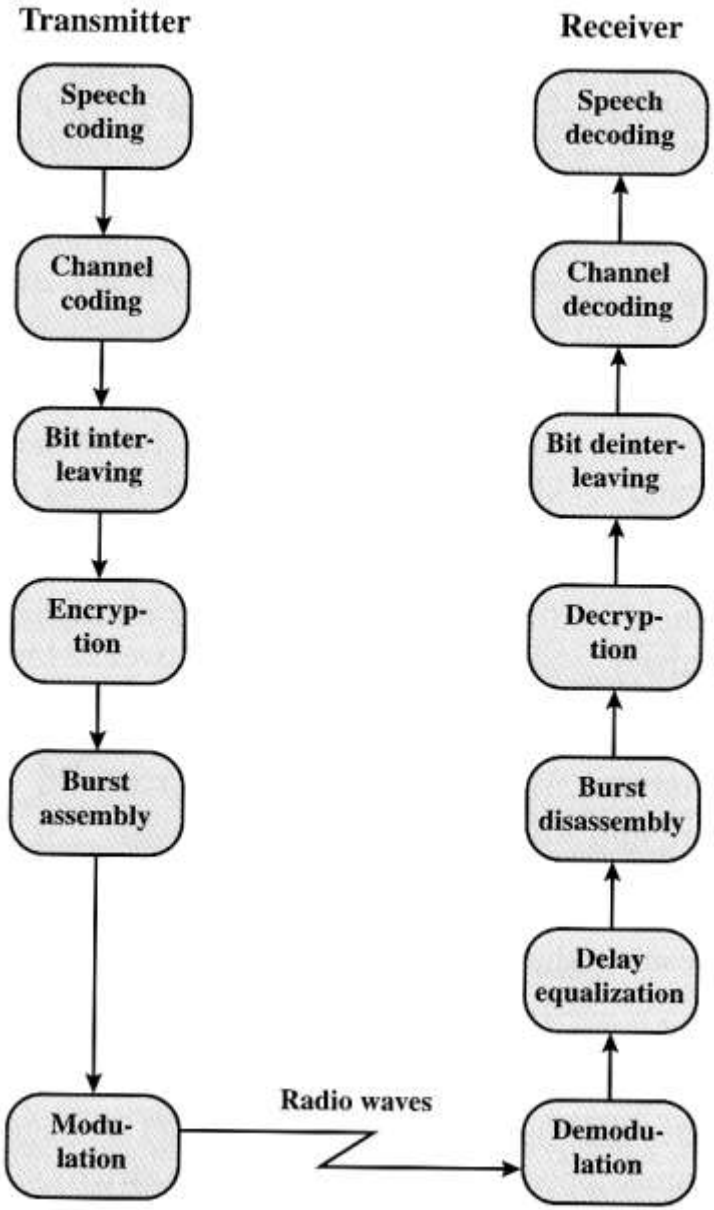
The GSM Voice Coder



The original signal, the predicted signal, and the long term predictor output signal



The GSM Speech Signal Processing



Network development trends