Introduction to cellular systems

IoT, a.a. 2018/2019

Un. of Rome "La Sapienza"

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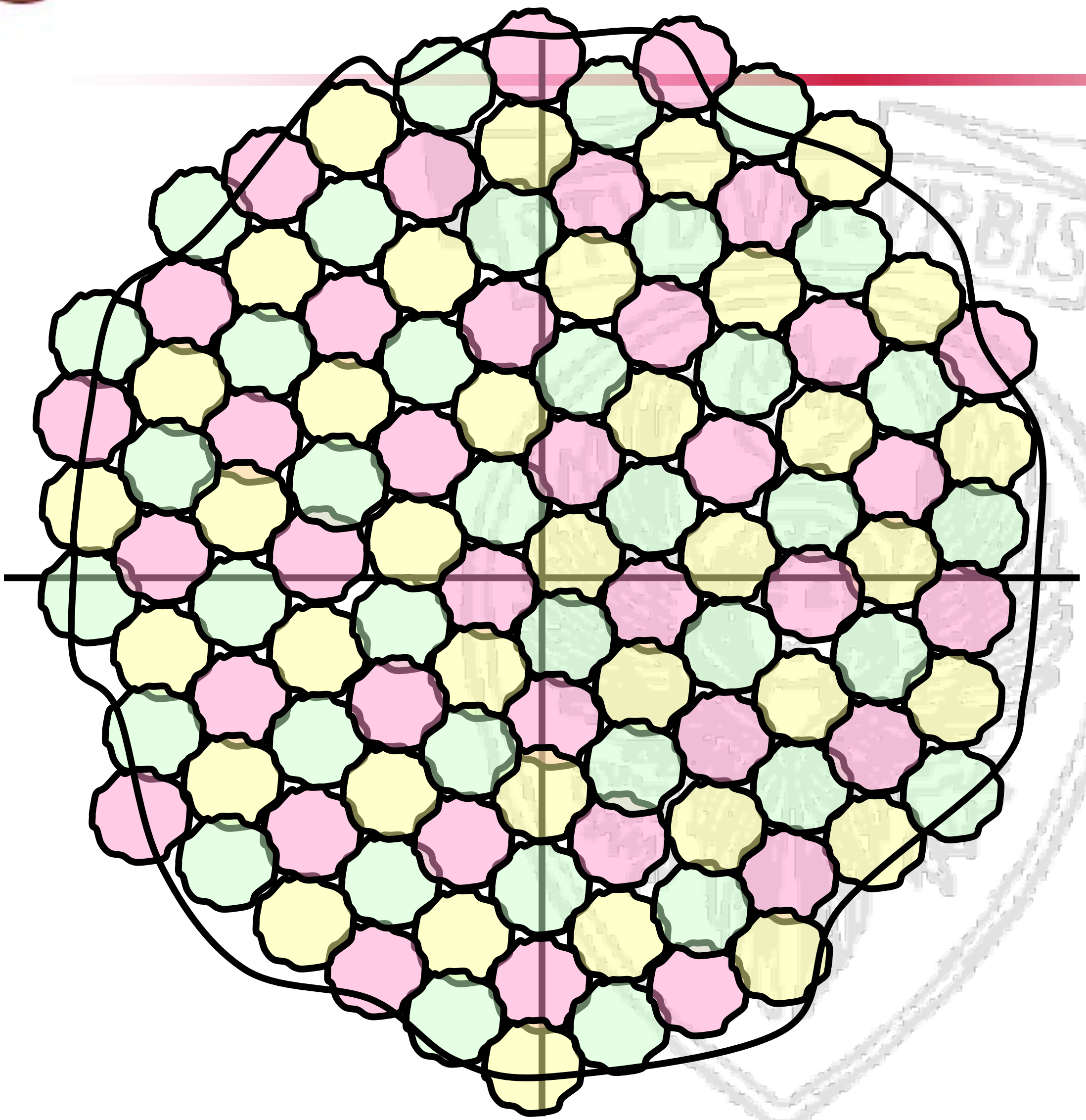
Mobility management

Cellular coverage (microcells)



many BS

Very low power!!

Unlimited capacity!!

Usage of same spectrum

(12 frequencies)

(4 freq/cell)

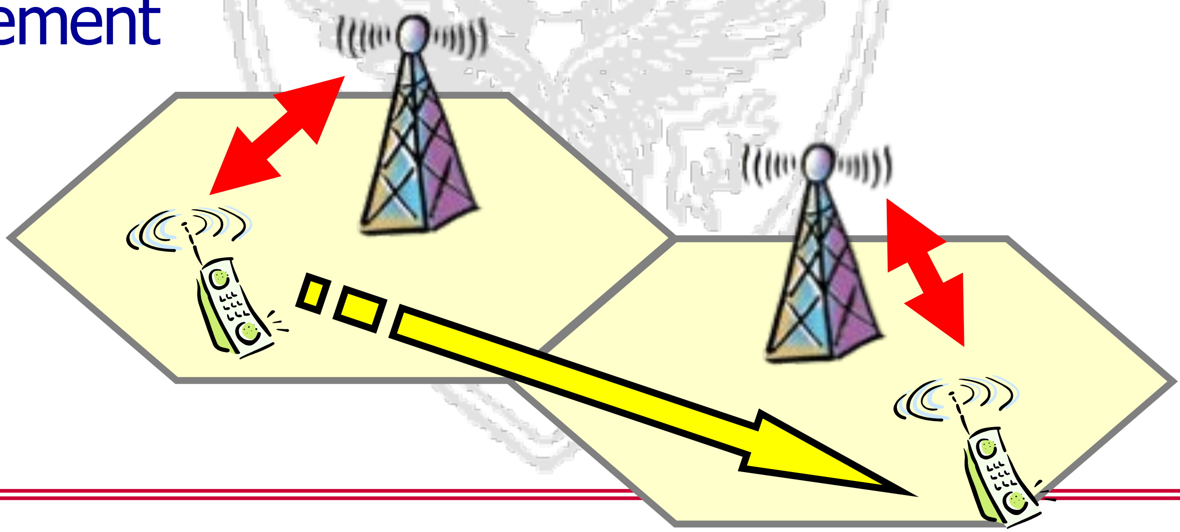
Disadvantage:

mobility management

additional infrastructure costs

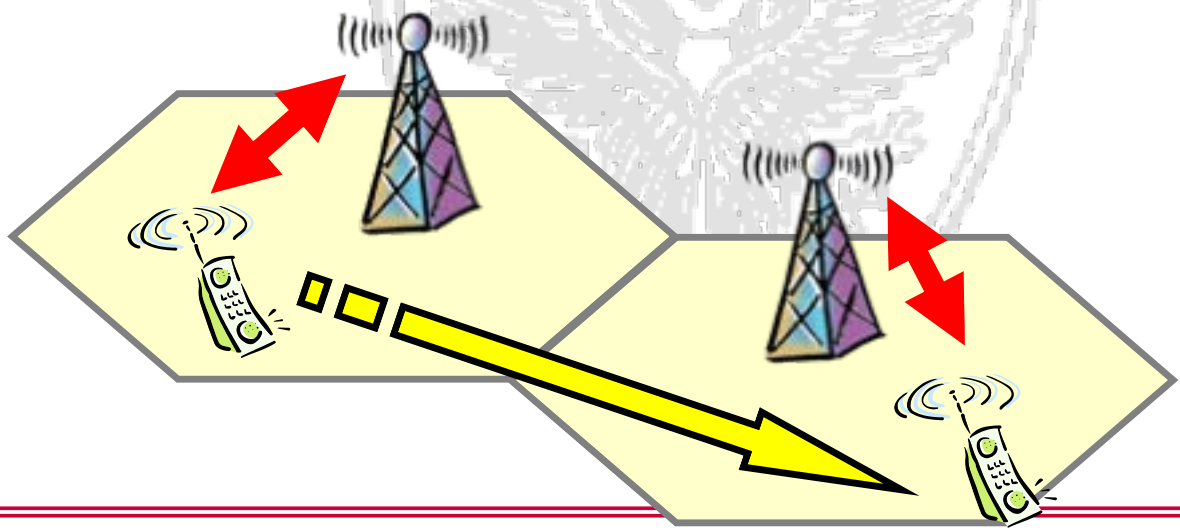
Mobility management

- cellular networks, users can move around in the system and then move from one cell to another
- This obviously poses problems of routing information (or more simply of the calls in the case of voice service)
- All procedures that the network puts in place to enable mobile users to be reached by a communication and maintain active communication even in the presence of a change of the cell go under the name of mobility management



Mobility management

- Users of cellular systems WHILE MOVING can:
  - call out
  - be called
  - converse
- And there should be some "intelligence" that supports this.



Mobility management

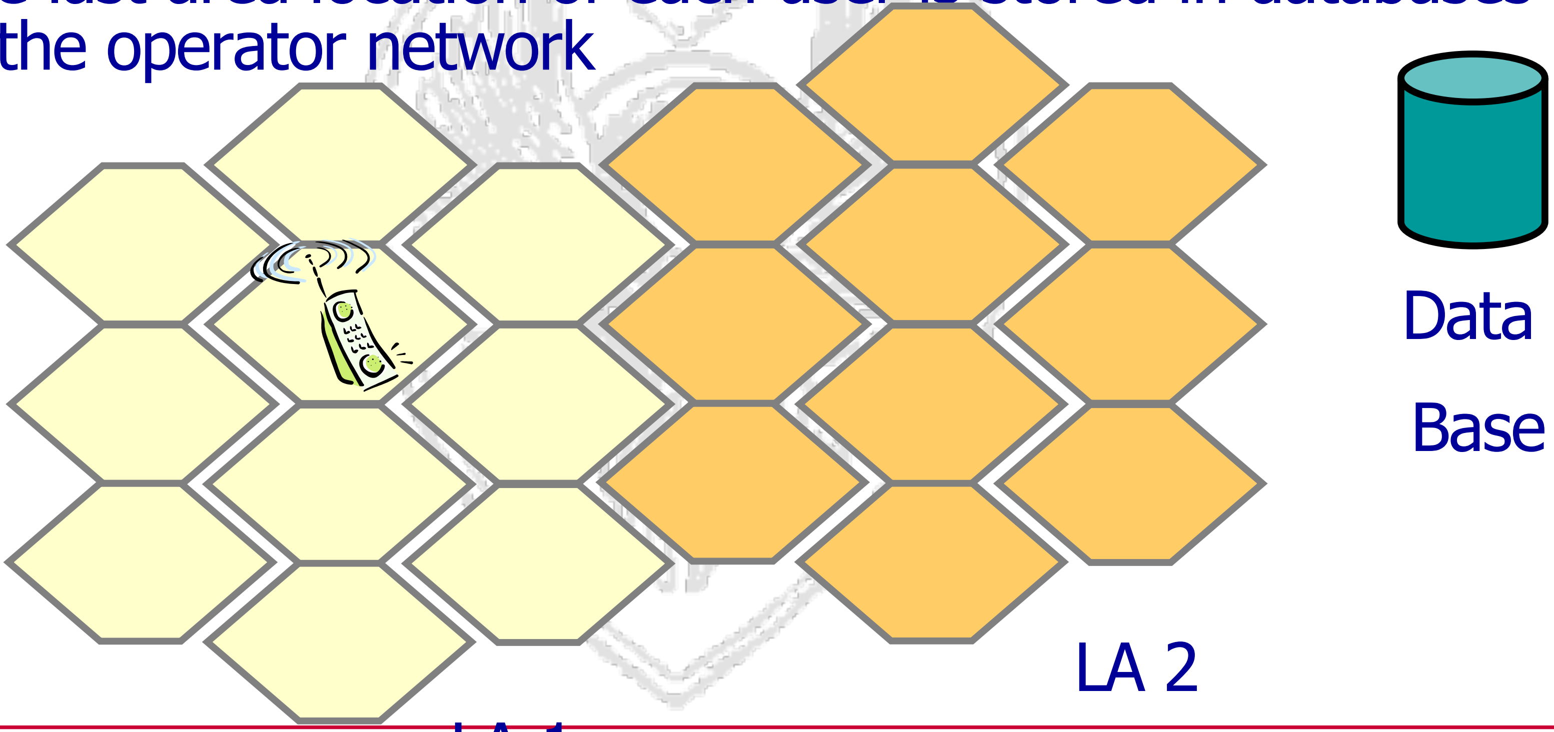
- In the case of circuit service mobility management procedures differ depending on whether the user is moving in the IDLE state (no active circuit) or ACTIVE (in conversation)
- ACTIVE: there is an active circuit that needs to be re-routed after every change of the cell (handover)
- IDLE: the user must be able to be located to be able to establish a call to/from him/her (*Location Update, Cell Selection, Cell Reselection*)

Cell selection

- A mobile terminal in idle mode "locks" to a cell on the basis of the signal received from the base station
- On a suitable common control channel the radio base station transmits the information of the system that, among other things, specifies its identifier
- The mobile terminal scans the radio frequencies to decode the control channel of the base stations in the area
- The terminal selects the base station from which it receives the strongest signal
- Periodically we continue to take steps (if the MS is in IDLE) on the signal received from the base station adjacent; if you get better from a different base station you make a cell reselection

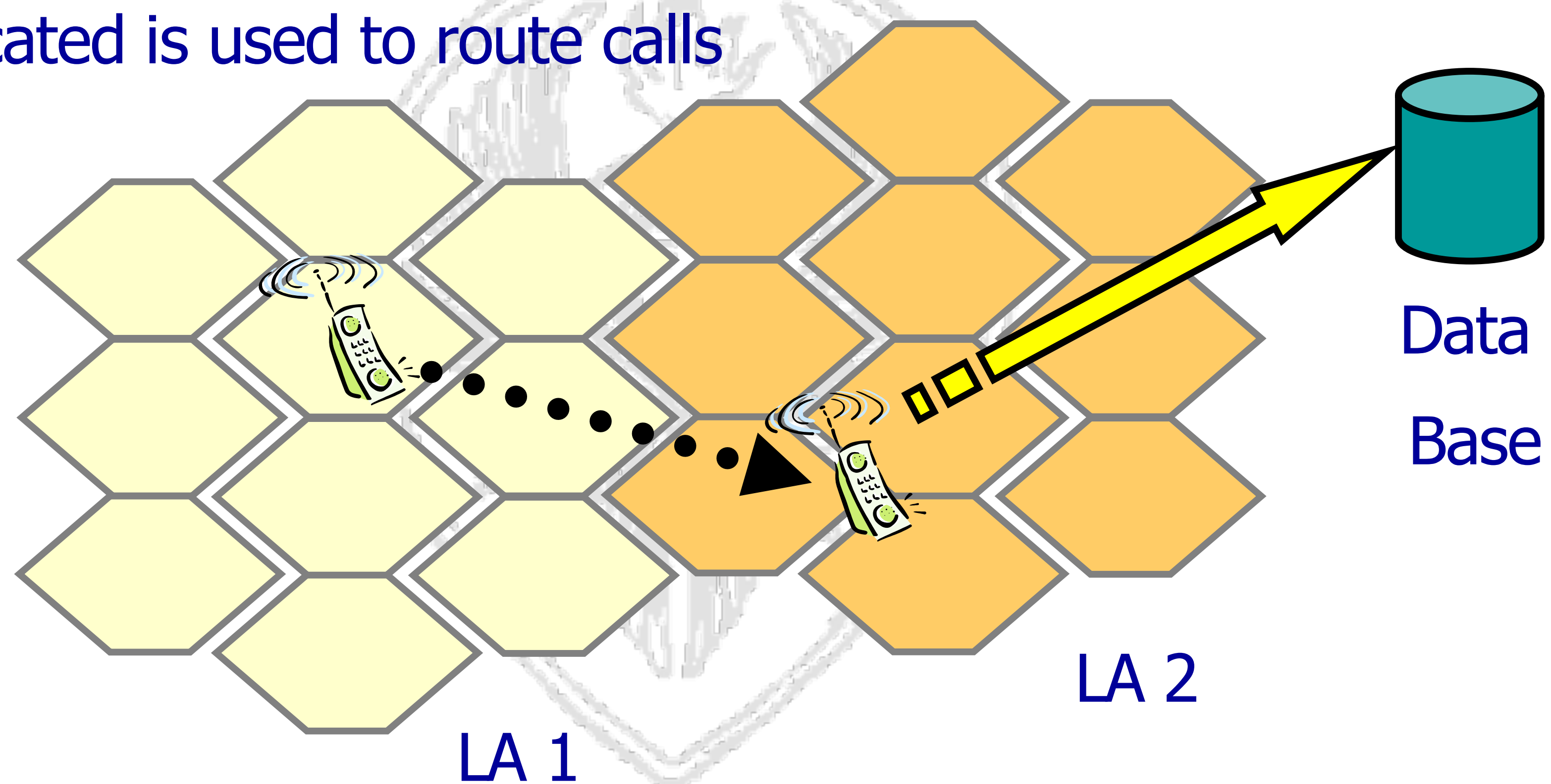
Location Update

- Location Area: topological entity that is hierarchically superior to the cell (group of several cells)
- An IDLE user is tracked by the system based on Location Area (and not on the basis of its cell)
- The last area location of each user is stored in databases of the operator network



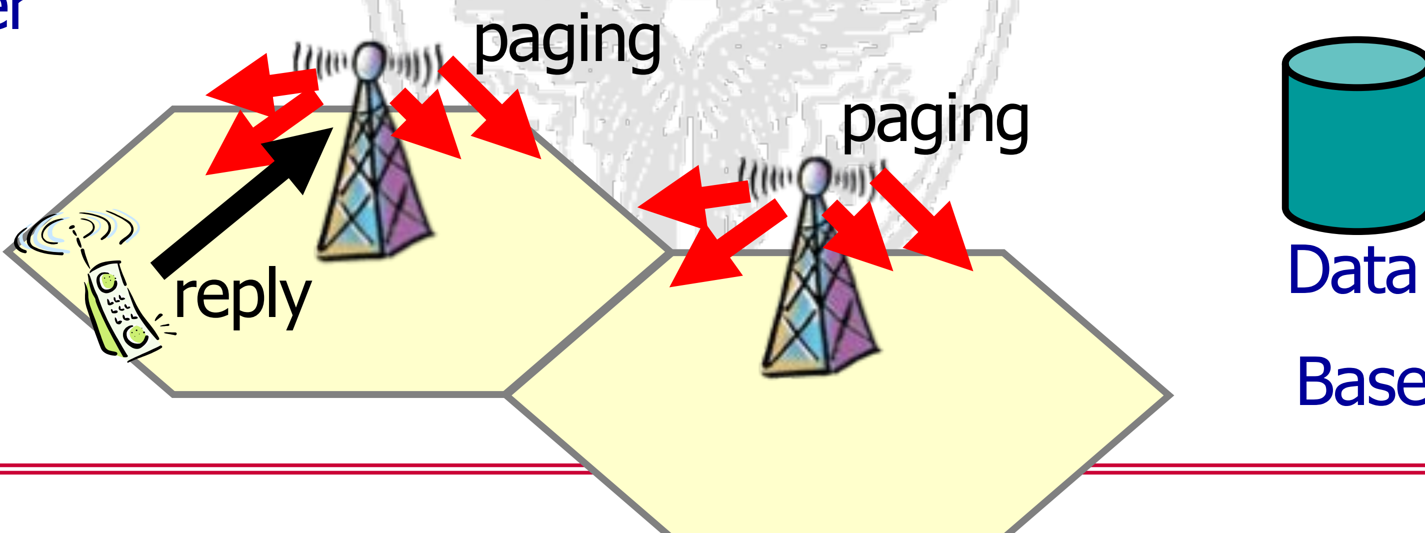
Location Update

- If a user in the IDLE state moves from one LA to another, it triggers a Location Update procedure
- The information about the LA in which a user is located is used to route calls



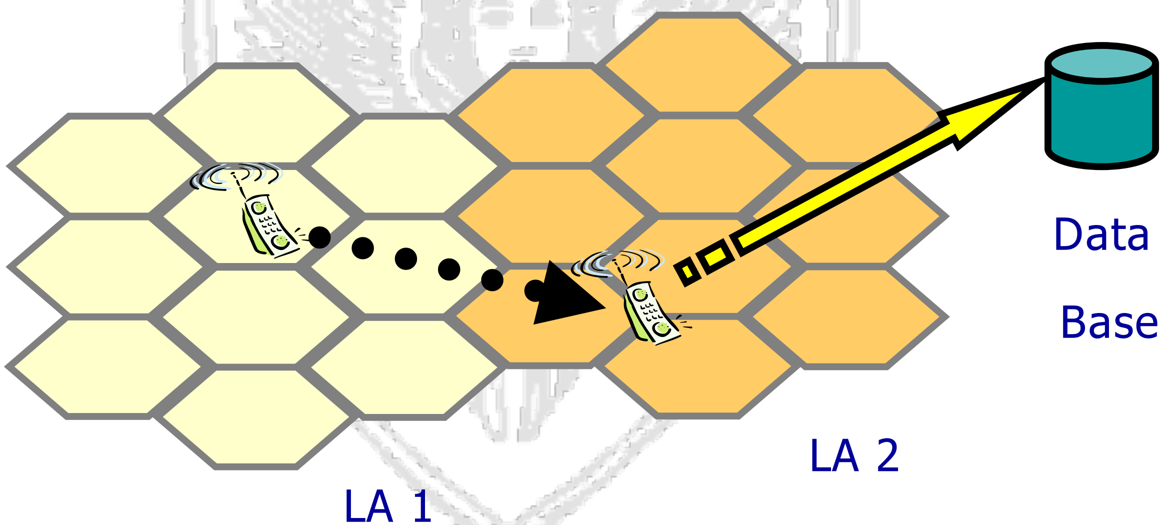
Paging

- When a call arrives for the mobile user the operatore is queried for the current user LA
- Once we know the location area where the user is located, the network initiates a paging procedure
- Each base station in the LA sends a control message broadcast with the ID of the user ID
- When the mobile terminal answers the network knows the cell and routes the call through the cell BTS till the mobile user



Paging vs. Location Update

- QUESTION:
- How big should the Location Area be?
  - small
  - large
- What drives in one direction, what in the other?

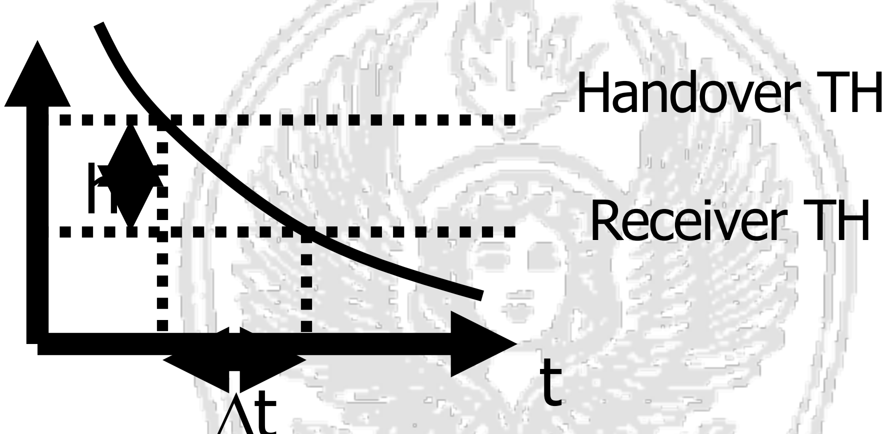


Handover

- Procedure by which a mobile terminal in conversation changes the base station it is affiliated to
- In network-controlled handoff and mobile assisted handoff (NCHO and MAHO) the procedure is always initiated by the network, on the basis of measurements (received signal strength, quality, etc.) carried out by both the network and the user side
- Handover procedures must be efficient and fast
- We will see in the case of GSM how handover procedures are managed from the point of view of network signaling and of the routing of the circuit

When to trigger an handover?

- The choice of the thresholds of activation of the handover procedure is a critical factor



- If h is too small It is too small and you risk loosing the connection
- If h is large the number of requests for handover increases, so also the signaling traffic in the network

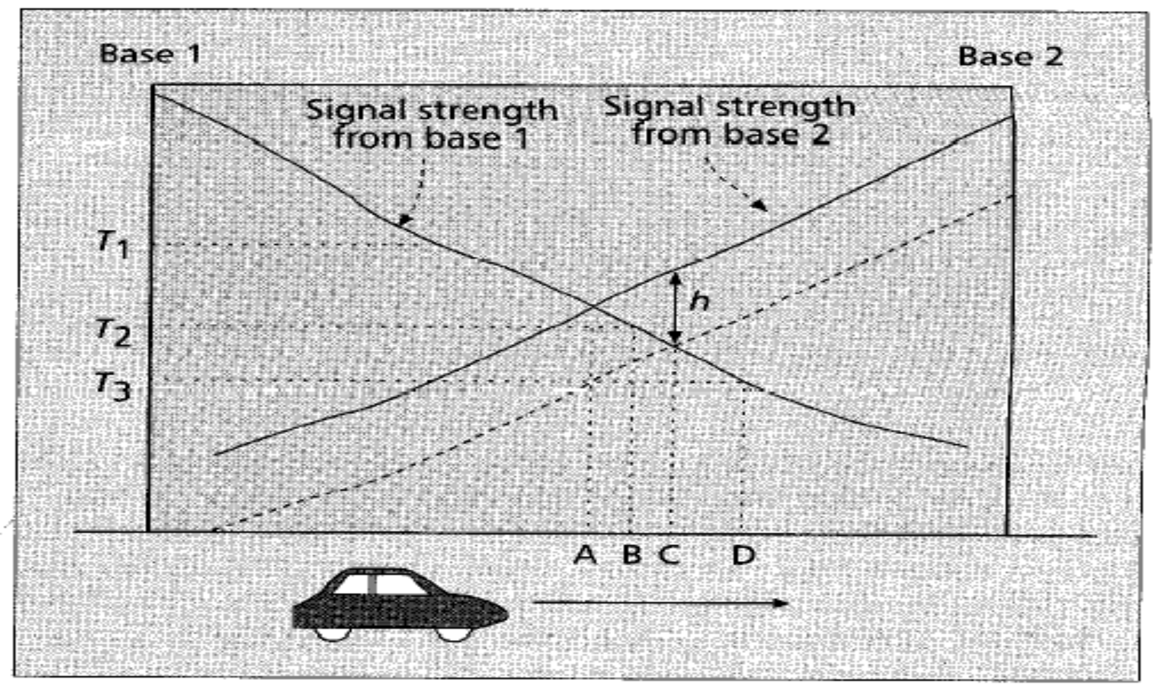
When to trigger an handover?

- There are several methods

1 - method of the strongest signal

  - the handover occurs at point A

due to the fluctuations of the signal many cell changes are possible (ping-pong effect)

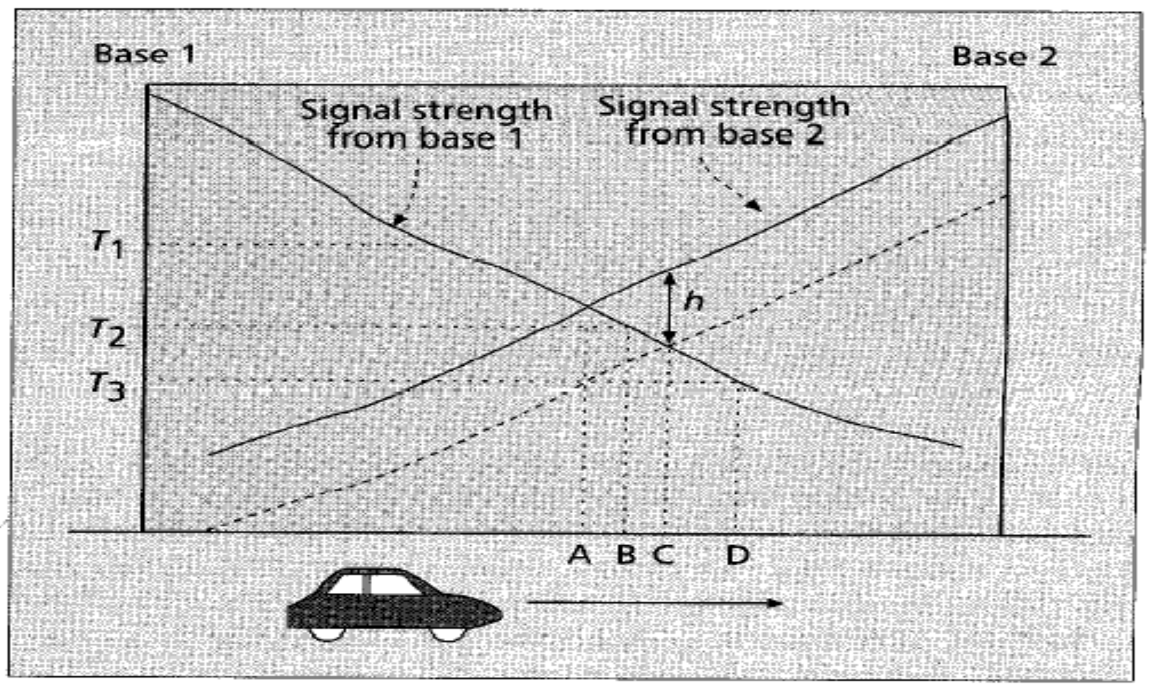


When to trigger an handover?

- There are several methods

2 - method of the strongest signal with the threshold

  – if the signal received from the previous BS is less than a threshold (as. eg. T2) and the power of another BS is stronger; the handover occurs at point B

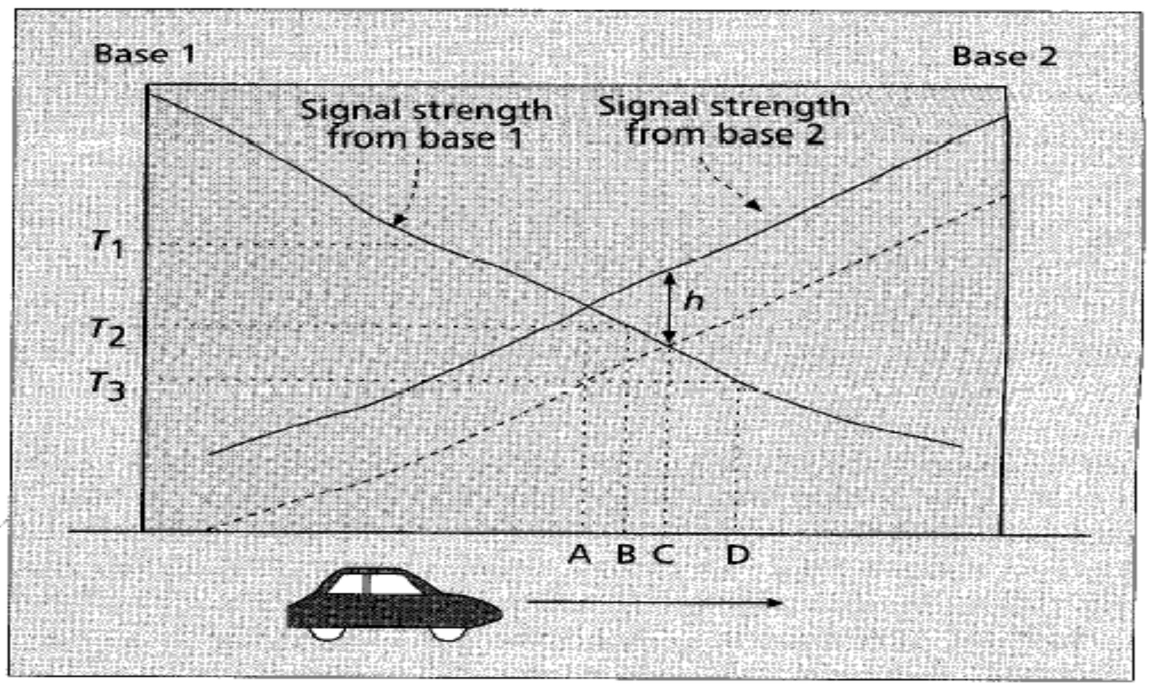


When to trigger an handover?

- There are several methods

3 - method of the strongest signal with hysteresis

  – if the power of the other BS is stronger than a value ☐ h; the handover occurs at the point C



Handover performance

- When there is a handover the channel in the old cell is released and the new channel is requested;
  - Problem: a channel in the new cell may not be available
- We define the probability of rejecting an handover (Pdrop) as the probability that a handover request can not be met and the blocking probability (Pblock) as the probability of rejecting a new call
- In systems that deal with requests for handover as the new incoming requests (call setup) Pdrop = Pblock
- In fact it is better to block an incoming call that loosing one active
- You can think of better treat requests for handover

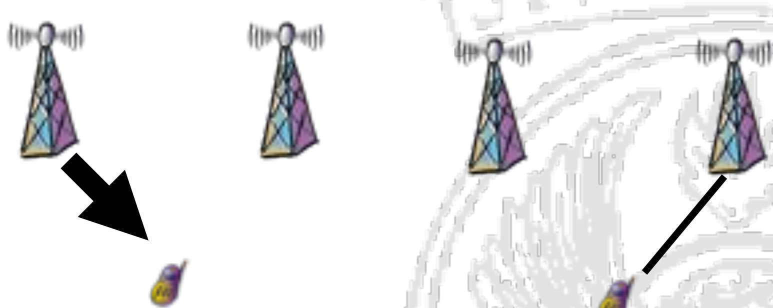
Handover performance guard channels technique

- Guard Channels
  - A number of channels is reserved for handover requests
  - Pdrop becomes lower but the capacity of the system is lower
  - System dimensioning is critical and requires accurate estimates of the traffic dynamics (how many channels should I reserve for handover requests?)

- Other Options
  - Queuing priority scheme
    - ✓ Handoff area: area within which the MS can hear both base stations. If no channels are available in the new BS the user will continue to be interconnected to the old BS; the request for handover to the new BS is buffered and served as soon as a channel is freed.
  - Subrating scheme
    - ✓ If there are no channels available at the new Base Station a channel previously allocated to a call is divided into two channels each half rate, allowing both calls to go forward.

Types of handover

- Hard Handover (GSM-2G)



Removal and establishment of a new radio link

- Soft Handover (UMTS-3G)

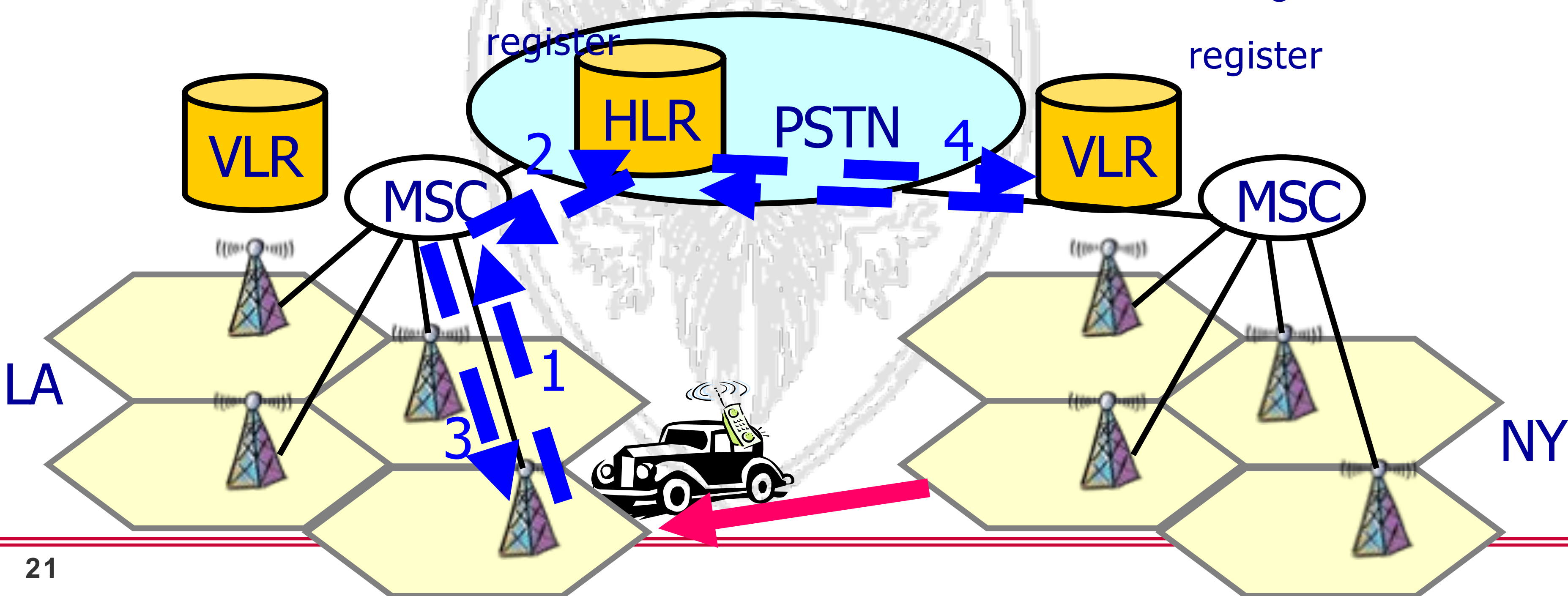
Leveraging on the user macrodiversity, the user is simultaneously connected to several base stations

Roaming

1. Upon arrival in a new LA, the user must register with the new VLR
2. The new VLR informs the HLR of the user's new location. The HLR sends back an ack with information such as the user's profile
3. The new VLR informs the user of the successful registration
4. The HLR sends a deregistration message to the old VLR

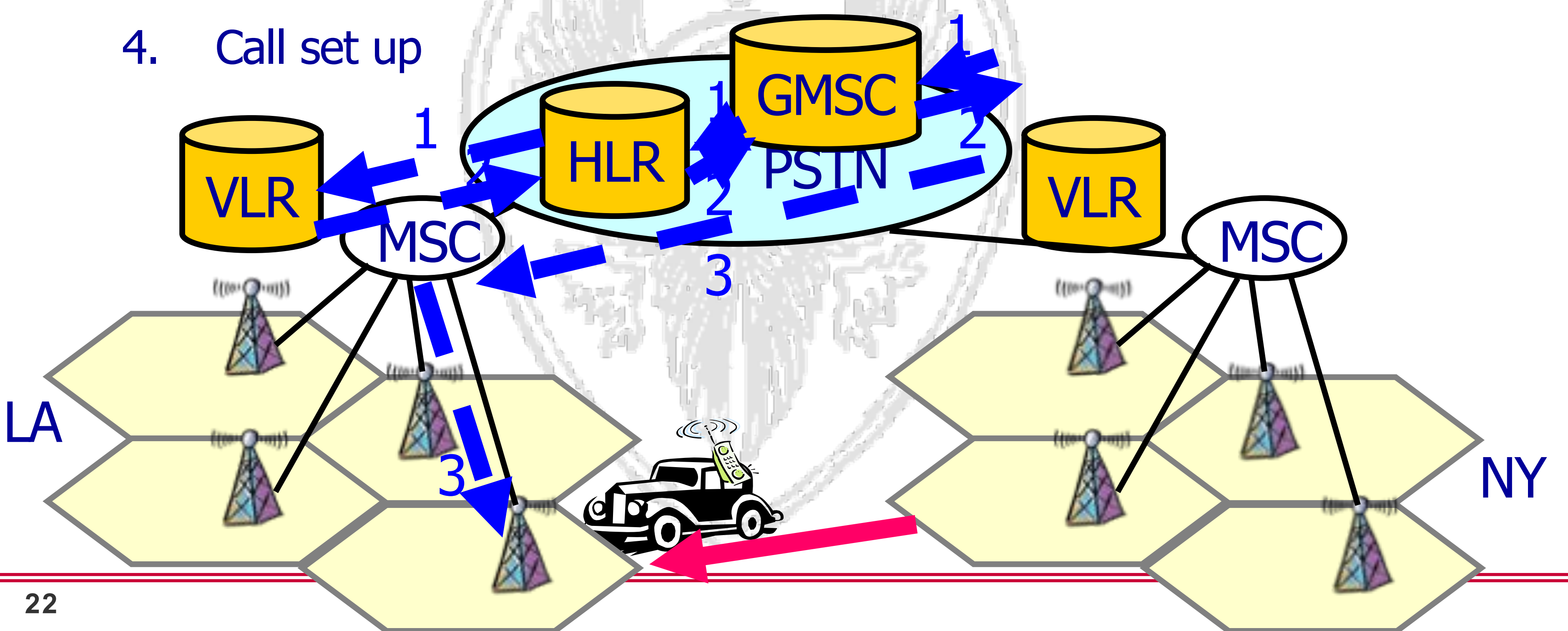
HLR: Home location register

VLR: Visiting location register



Call set up : example

1. MS→fixed phone through the VLR of the MS
2. Fixed phone→MS:through the gateway MSC of the MS the caller contacts the HLR and , throught it, the VLR currently managing the user
3. VLR provides information such as a routing number, LA of the user
4. Call set up



Cellular systems & GSM

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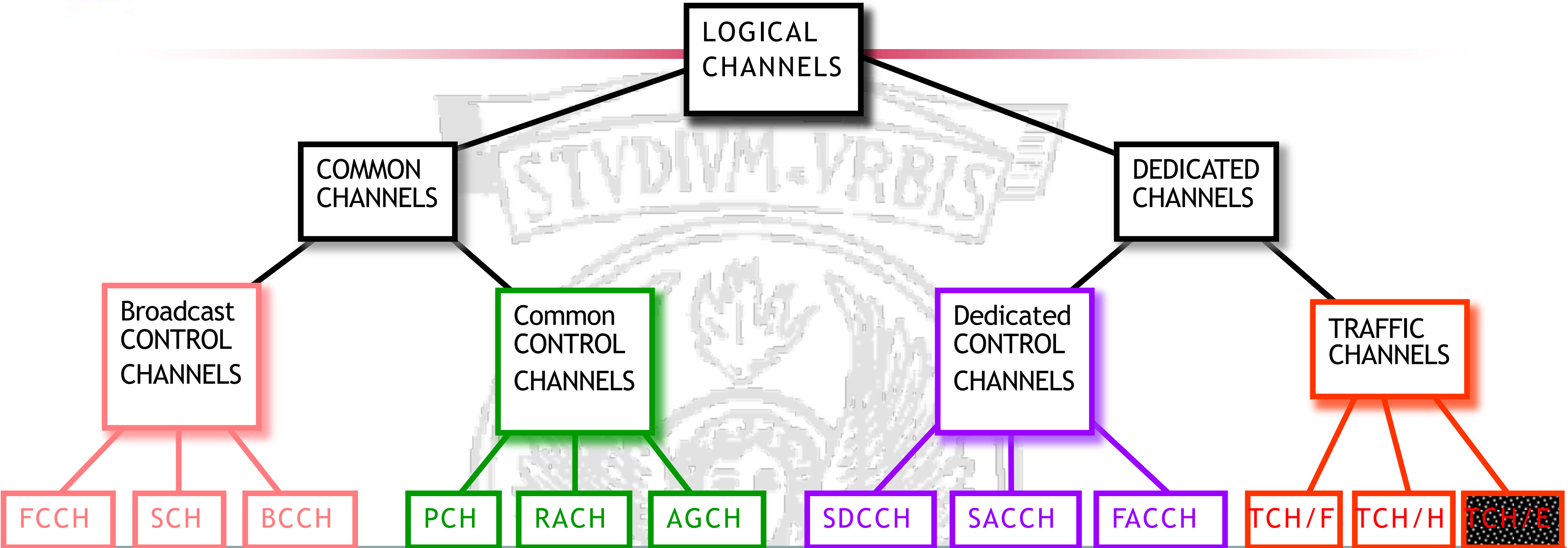
Logical Channels

- Uniquely identify the type of information they carry:
  - Signaling (e.g., synchronization info, ...)
  - Data traffic
- Channels types:
  - Traffic channels vs. control channels
  - Common channels vs. dedicated channels

Logical Channels



FCCH=Frequency Correction CHannel

SCH=Synchronisation Channel

BCCH=Broadcast Control CHannel

PCH=Paging CHannel

RACH=Random Access CHannel

AGCH=Access Grant CHannel

SDCCH=Stand-alone Dedicated Control CHannel

SACCH=Slow Associated Control CHannel

FACCH=Fast Associated Control CHannel

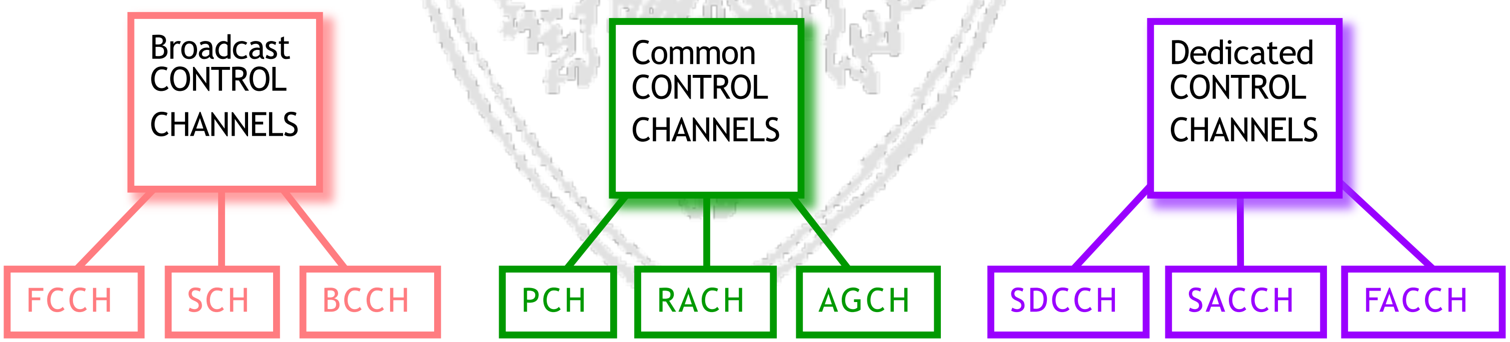
TCH/F=Traffic CHannel Full rate

TCH/H=Traffic CHannel Half rate

TCH/E=Traffic CHannel Enhanced Full rate

Control Channels-CCH

- Control channels carry signaling information (14 types of control channels are defined!!)
- Three main categories of CCH:
  - Broadcast Channels (BCH): unidirectional downlink channels providing general information about the network
  - Common Control Channels (CCCH): carry information for initiating a connection (shared between multiple connections)
  - Dedicated Control Channels (DCCH): carry signaling information specific for a single connection



Broadcast Channels - BCH

- FCCH (Frequency Correction Channel): downlink channel used to correct MS frequency, 148 bits without coding
- SCH (Synchronization Channel): carry the Base Station Identity Code (BSIC) and the frame number (FN), 25 bits + channel coding
- BCCH (Broadcast Control Channel): carry general information that are broadcasted to all user of a base station, 184 bytes after coding (parameters of the frequency hopping algorithm, number of common control channels allocated, number of blocks for the AGCH channel, etc.).

Broadcast
CONTROL
CHANNELS

Common Control Channels - CCCH

- PCH (Paging Channel): downlink channel used by the BTS to notify an incoming call to a MS, broadcasted over a LA
- RACH (Random Access Channel): uplink channel used by a MS to request access to the network (Location Update, call request). Prone to collisions.
- AGCH (Access Grant Channel): downlink channel carrying reply to RACH requests.

Common
CONTROL
CHANNELS

Random Access Channel (RACH)

- Access to the RACH channel is random, i.e., not coordinated with other MSs
- The RACH channel is thus prone to collisions
- Access messages that are correctly received by the BS are acknowledged on the AGCH channel
- RACH messages include a temporary pseudo-random sequence that is included on the acknowledgment sent on the AGCH channel

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- Transmissions on the RACH channel use the *Slotted-ALOHA* protocol

Dedicated Control Channels – DCCH

- SACCH (Slow Associated Control Channel): bidirectional channel used to exchange connection metrics between MS/BS and BS/MS (e.g., received signal strength, quality….). Multiplexed with user traffic (184 bits)
- FACCH (Fast Associated Control Channel): used for exchange of time critical information (urgent handover request). The FACCH transmits control information by "stealing" capacity from the associated traffic channel.
- SDCCH (Stand-alone Dedicated Channel): stand-alone dedicated control channel that is assigned after a RACH request (authentication messages, call set-up…)

Dedicated
CONTROL
CHANNELS

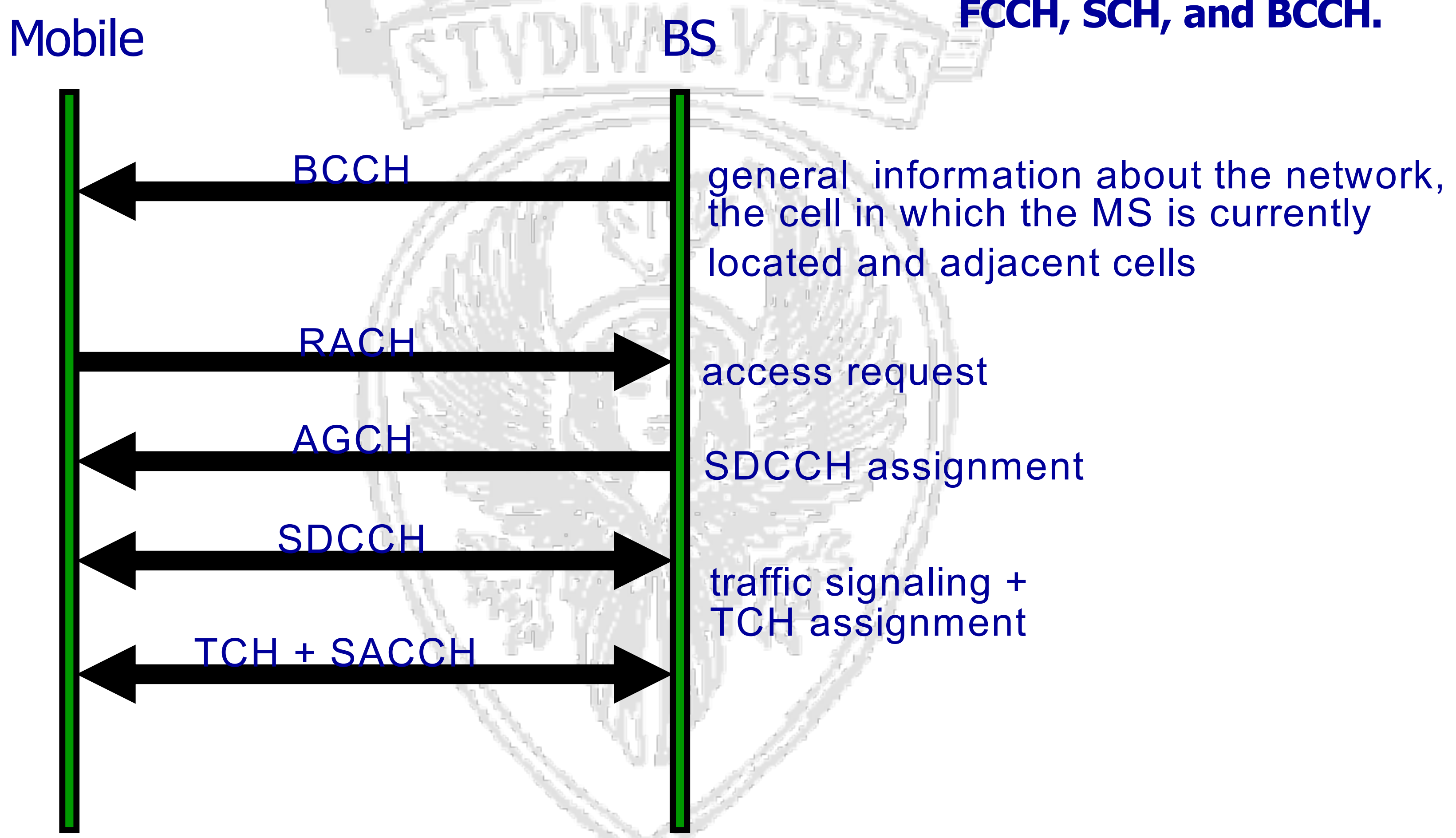
Slow Associated Control Channel (SACCH)

- Downlink:
  - Power control commands
  - BCCH information (that can no longer be decoded by the MS after it switches to the traffic channel)
- Uplink: MS measurements report:
  - RXLEV-SERVING-CELL (signal strength from own BTS) RXQUAL-SERVING-CELL (downlink BER)
  - RXLEV-NCELL “N” (signal strength from adjacent cells)
  - BCCH-FREQ-NCELL “N” (# BCCH carrier of adjacent cells)
  - BSIC-NCELL “N” (BSIC of adjacent cells)

Dedicated CONTROL CHANNELS

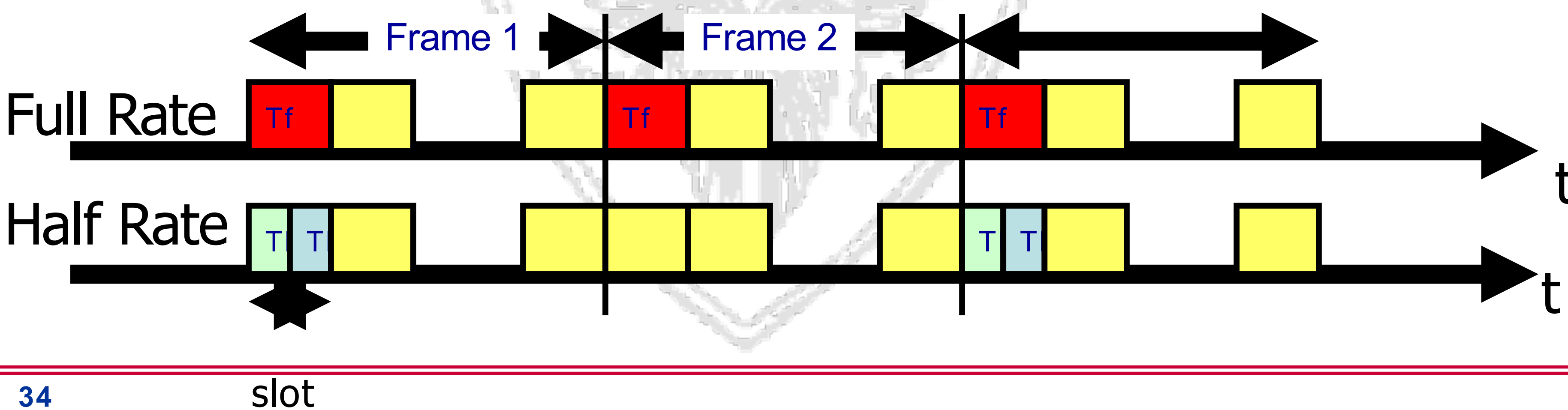
Set-up of a traffic channel

The MS tunes to a BTS and synchronizes with the frame structure in its cell by using FCCH, SCH, and BCCH.



Traffic Channels-TCH

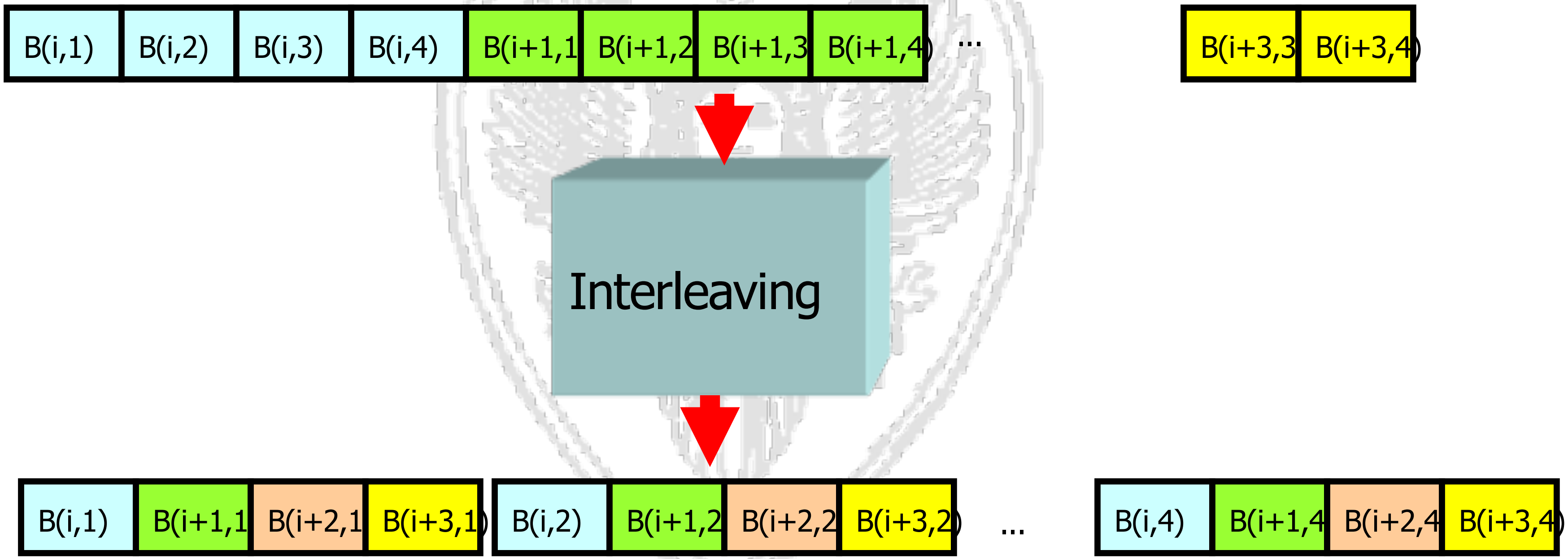
- Traffic channels (TCH) carry speech and data
- Two types of TCH:
  - Full Rate channels: gross rate of 22,8 Kb/sec (including coding incorporated for error protection)
  - Half Rate channels: gross rate of 11,4 Kb/s



Channel coding: voice channel at 13 Kb/s

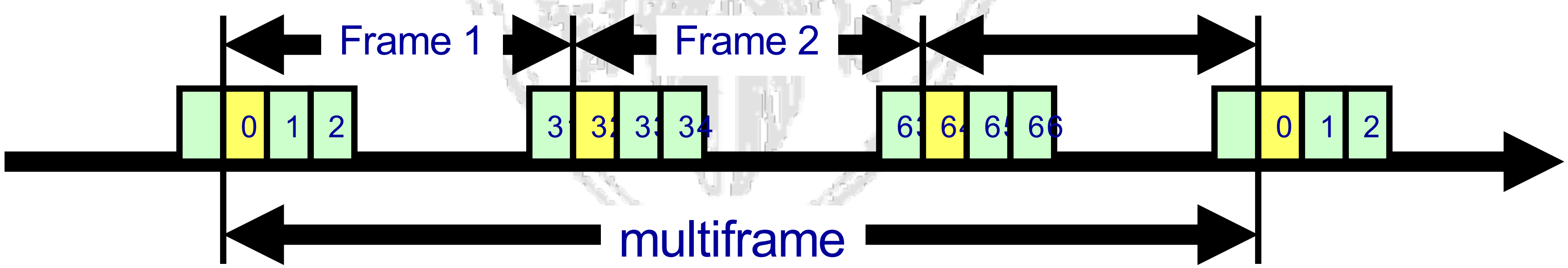
- Bit of the 4 physical blocks of 114 bit are not the contiguous output of the coding process
- Instead, bits are interleaved:

Interleaving



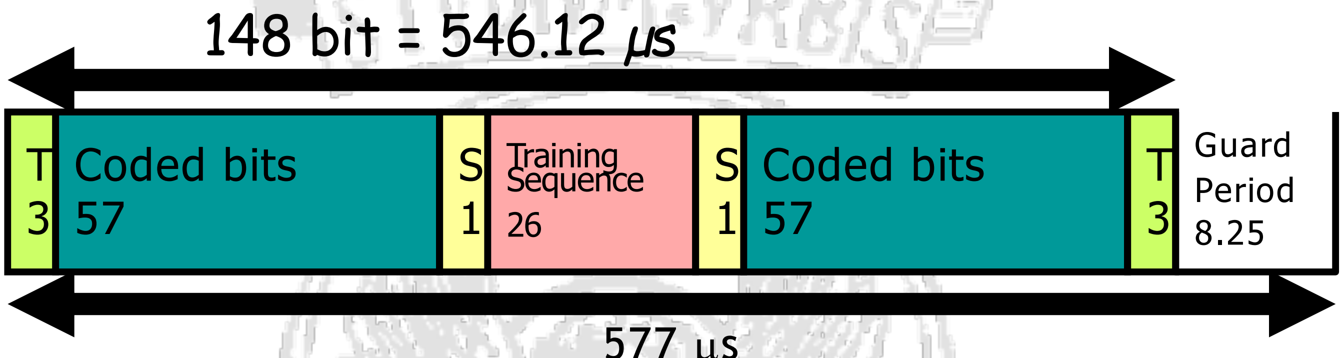
Mapping of logical channels onto physical channels

- Signaling requires lower bit rates than user transmissions (it wouldn't be efficient to assign a whole slot per frame to signaling)
- Actual transmission rate may be reduce by using **multiframes**
- IDEA: slots are associated with IDs, and may be assigned over a period of multiple frames, i.e., over a multiframe



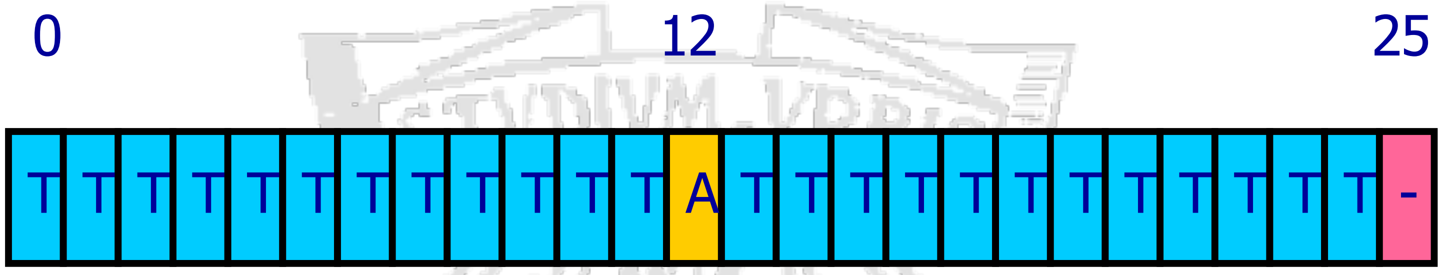
Multiframe example: SACCH

- A normal data burst carries 114 bits of data



- A channel using one slot per frame has a rate of 114 [bit]/4.6 [ms]=24.7 Kb/s
- Coded speech is transmitted at a rate of 22,8 Kb/s
- 1,9 Kb/s are not used, equal to 1 SLOT every 13 frames
- SACCH: 1 SLOT every 26 frames = rate of 950 bit/sec.

SACCH Signaling channels

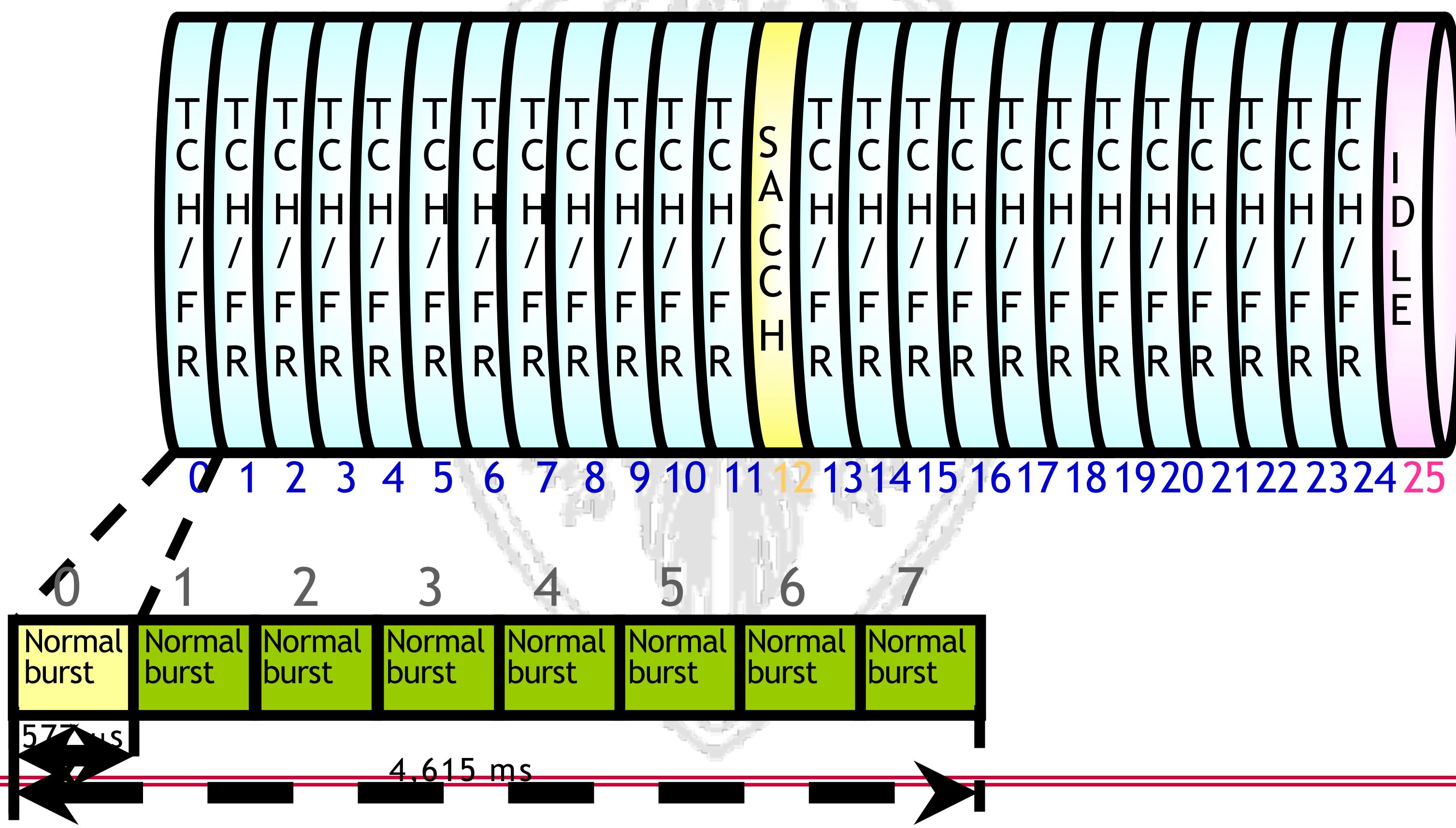


- The figure shows mapping of a full-rate traffic channel (TCH) (T) and its Slow Associated Control Channel (SACCH) (A) onto one physical channel
- SACCH is used for measurements exchange and commands
- A super-frame of 26 frames (120 ms) is used.

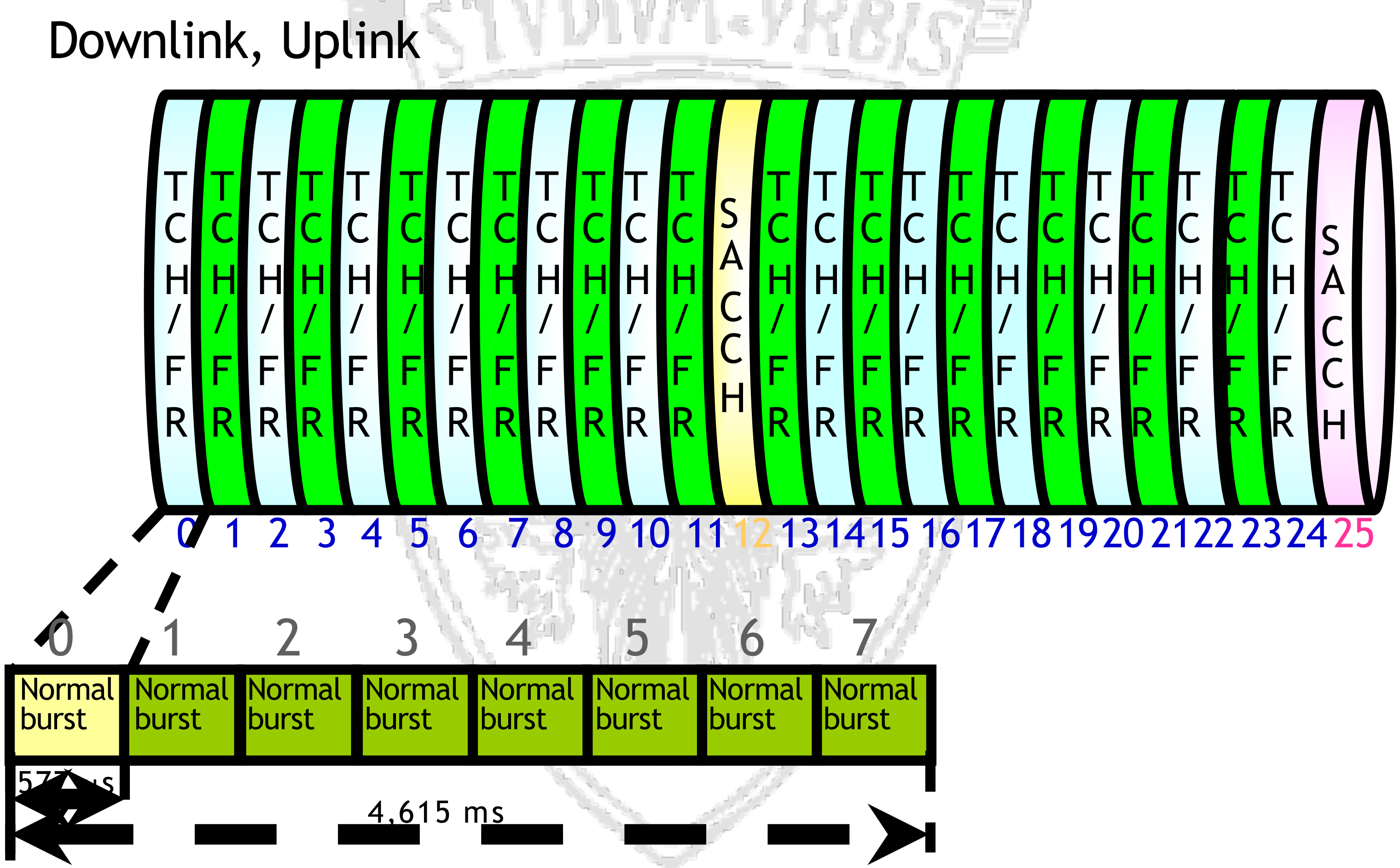
Multiframe TCH full duplex

- *A temporal diagram is the sequence of slots of the same traffic channel, i.e., of a slot of a frame*

Downlink, Uplink

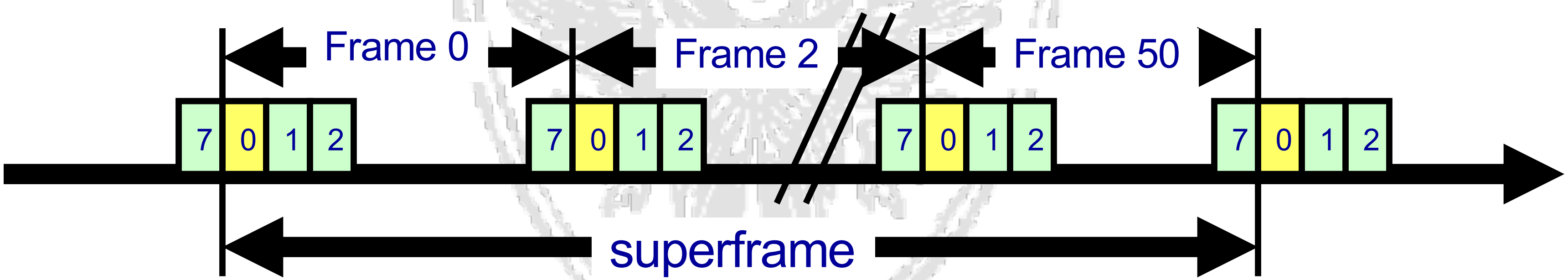


Multiframe TCH half duplex



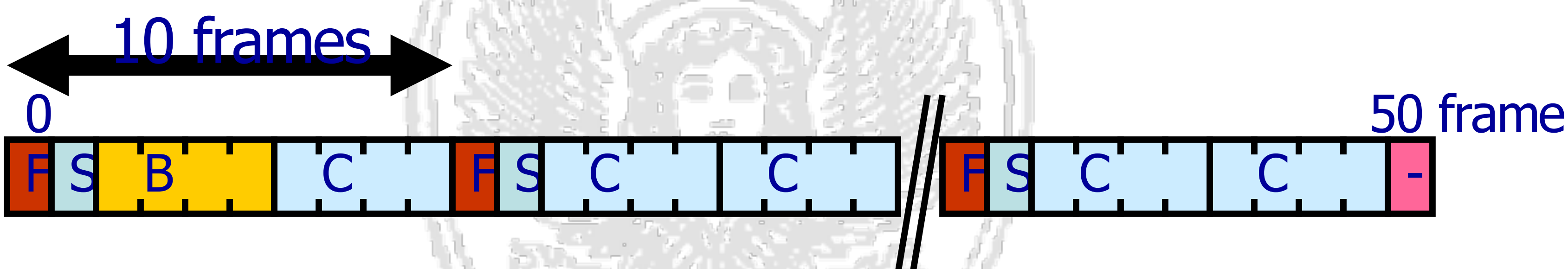
Common signaling channels

- A given slot (slot 0) over a given carrier (C0 or main carrier) among those associated to the cell is used to obtain one or multiple channels that use a multiframe containing 51 frames (235.38 ms).
- In downlink, the main carrier is always transmitted at a power higher than the other carriers, which allows a MS to synchronize with the main carrier and to receive the information it needs for tuning to the BS.



Common signalling channels

- Downlink channels:
  - Frequency Channel (FCH)
  - Synchronization Channel (SCH)
  - Broadcast Control Channel (BCCH)
  - Common Control Channel (PCH, AGCH in downlink)



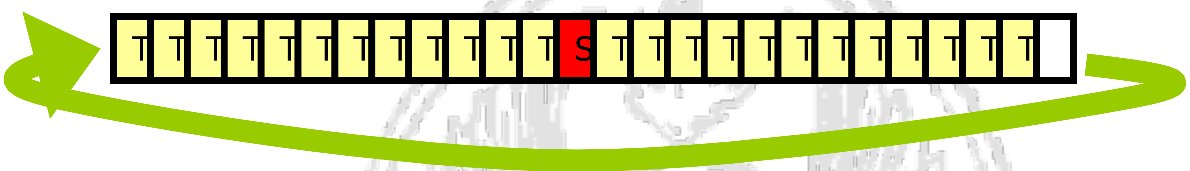
- Uplink: Random Access Channel (RACH)

SDCCH channel

- Another slot is used to obtain 8 Stand-Alone Dedicated Control Channel (SDCCH) (S)
- Used for setup and other messages (SMS)
- The 8 channels are obtained by using 3 slots each within the super-frame of 26 slots

Why 26 and 51?

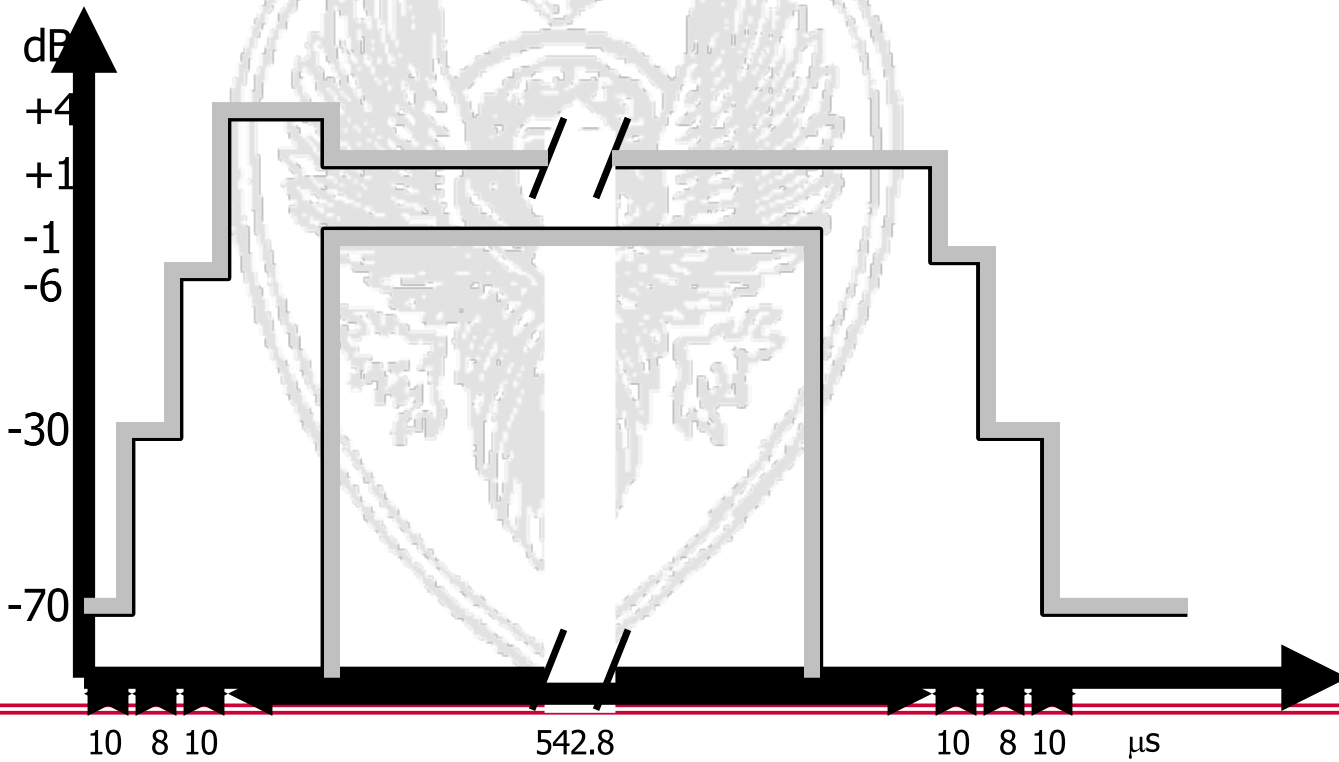
Last frame (idle) in TCH multiframe (Frame #25) used as "search frame"!



- An active call transmits/receive in 25 frames, except the last one.
- in this last frame, it can monitor the BCCH of this (and neighbor) cell
- this particular numbering allows to scan all BCCH slots during a superfran

Physical blocks (Bursts)

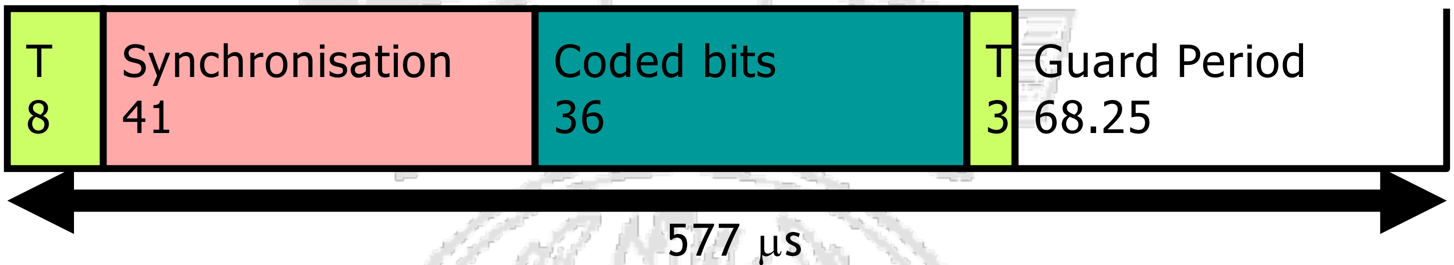
- The physical block is the information transmitted during a slot
- Due to TDMA, each block is an autonomous transmission entity, which should be transmitted at the appropriate power level to avoid interference with adjacent slots



Bursts Classification

- Normal Burst
  – Used for user transmissions (speech or data) over traffic channels
- Access Burst
  – Used to transmit information over the Random Access CHannel - RACH
  – First-time access
- Longer guard period (68,25 bit durations) to avoid overlapping of the the transmission from different mobiles; remember that mobile users do not know the timing advance at the first access (or after handover). The guard period is computed assuming a maximum cell size of 35Km.

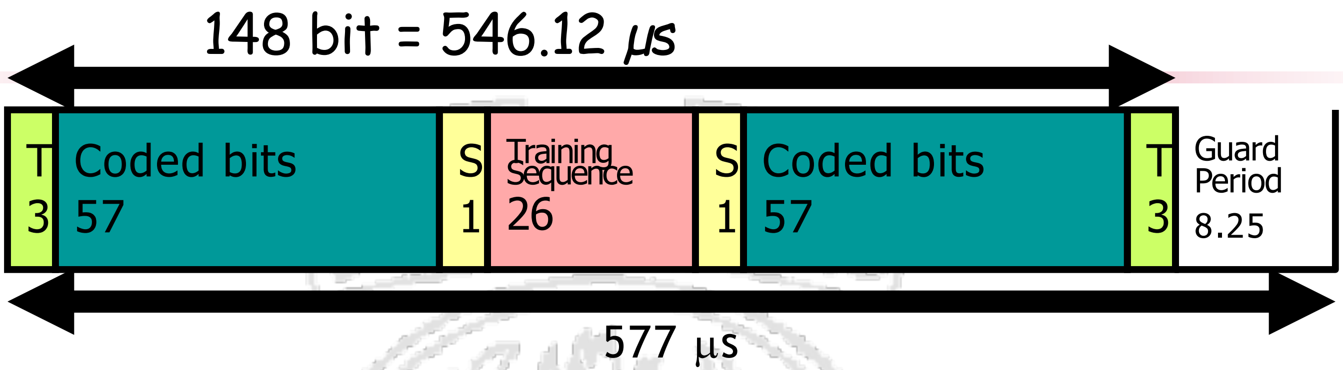
Access Burst



- Used by the MS on the random access channel at the first access
- Asynchronous access, no timing advance check
- It contains 156.25 bits
  - 8 tailing bits
  - 41 synchronisation sequence
  - 36 coded bits
  - 3 tailing bits
  - 68.25 bits guard period

To estimate timing advance

Normal Burst

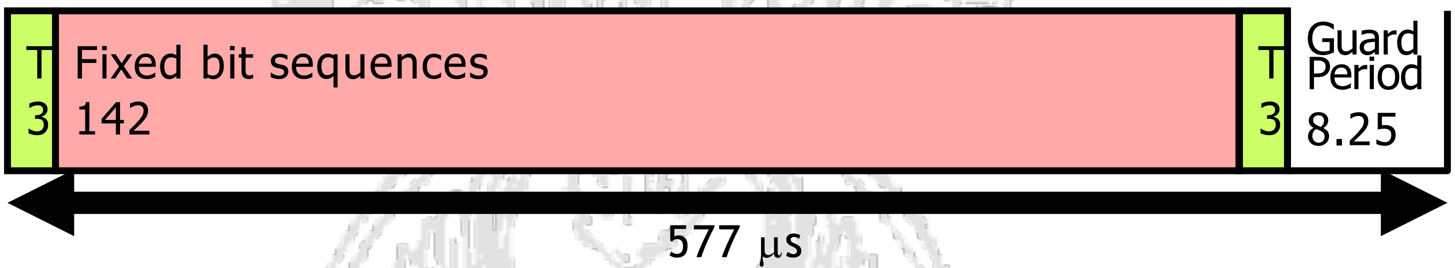


- T-bits: tail bits always set to 0
- S-bits: (stealing bits) indicate whether the burst contains user data or signaling information (SACCH or FACCH channels, only one of the two blocks may contain signaling information in case of FACCH)
- Coded Data: user bits (speech, data, etc.), 114 bit with channel coding, corresponding to 13 kbit/s for speech and to 9.6 kbit/s or lower for data (due to the channel coding using more bits)
- Training Sequence: control bits used for the equalization and tuning of the transmitters
- GP: guard period

Bursts Types

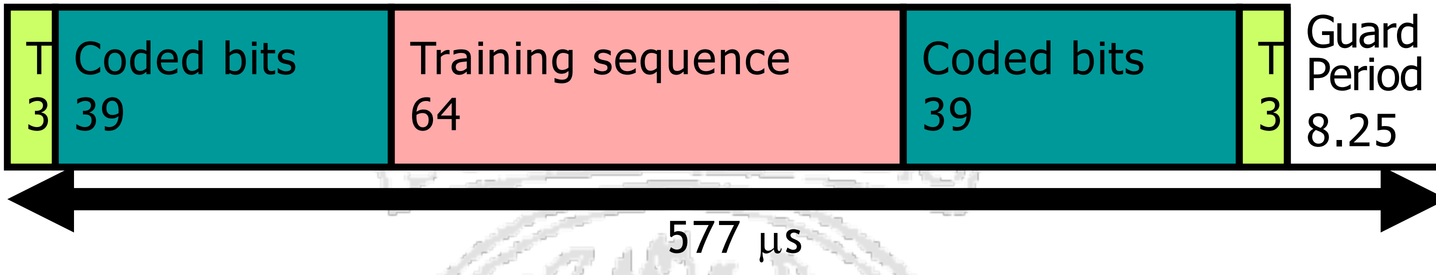
- Frequency Correction Burst
  - Used over the Frequency Correction Channel - FCCH
  - 142 bits set to “0”
  - Correct the frequency of the MS’s local oscillator, effectively locking it to that of the BTS
- Synchronisation Burst
  - Used to transmit information about synchronization for slots and frames
- Dummy Burst
  - It contains no information, only padding bits
  - Used when there is no information to be carried on the unused timeslots of the BCCH Carrier (downlink only)

Frequency Correction Burst



- 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 142 fixed bit sequences
    - ✓ All bits set to 0
    - ✓ a pure sine wave is transmitted, which is the frequency with which the MS has to tune with
  - 8,25 bits guard period

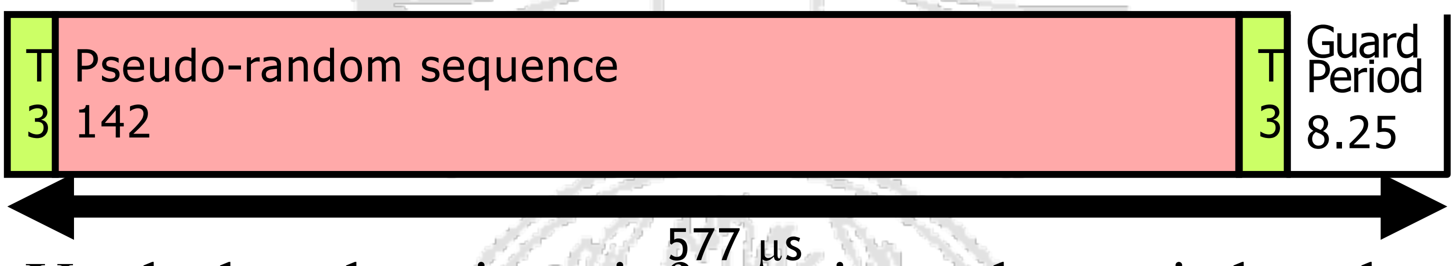
Synchronisation Burst



- 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 2 x 39 coded bits
    - ✓ 25 bit information
    - ✓ 78 bit with coding
    - ✓ Split into two pieces of 39 bit
  - 64 bit di training sequence
  - 8.25 bit guard period

Critical information, must be protected and correctly decoded

Dummy Burst



- Used when there is no information to be carried on the unused timeslots of the BCCH Carrier (downlink only).
- Measurements on signal strength must be carried out independently of whether there are data to transmit.
- Contains 148 + 8.25 bits
  - 2 x 3 tail control bits
  - 142 pseudo-random sequence
  - 8.25 bits guard period

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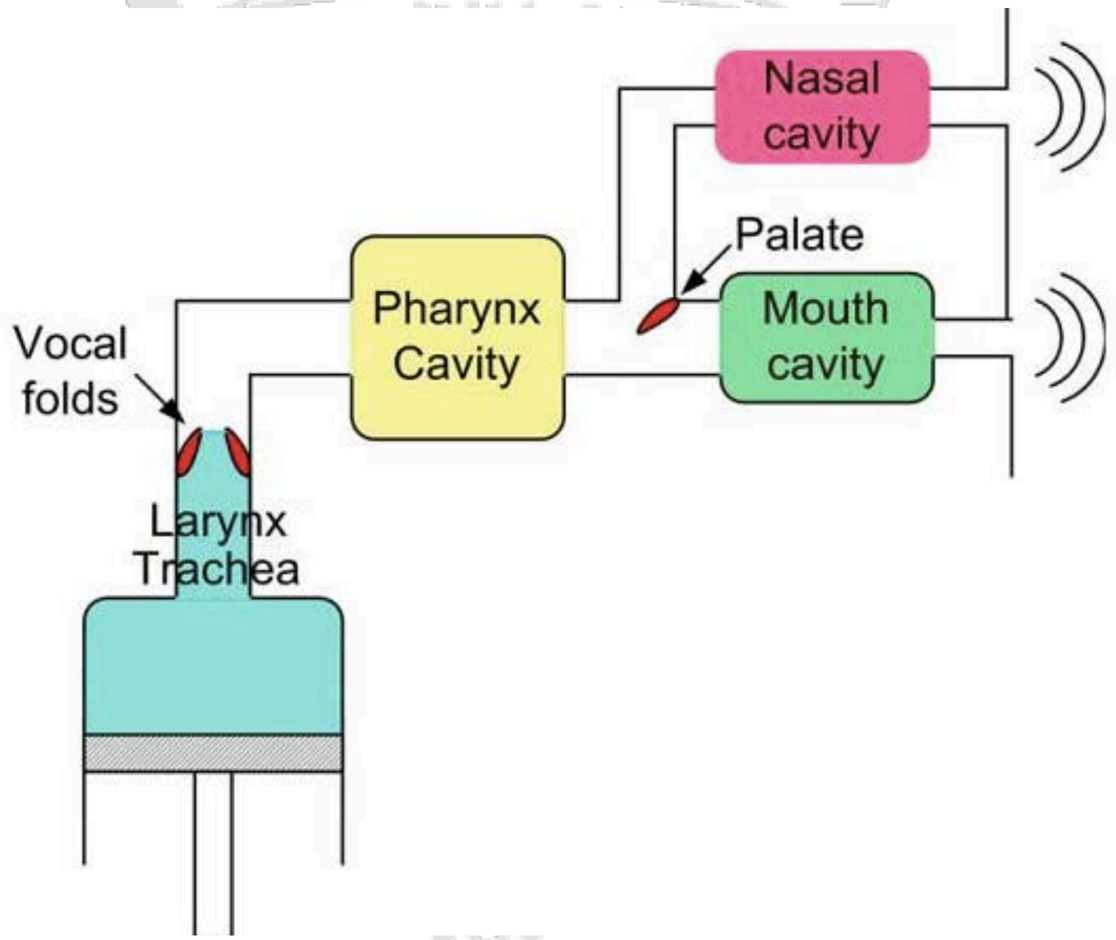
Voice Coding

Speech signals



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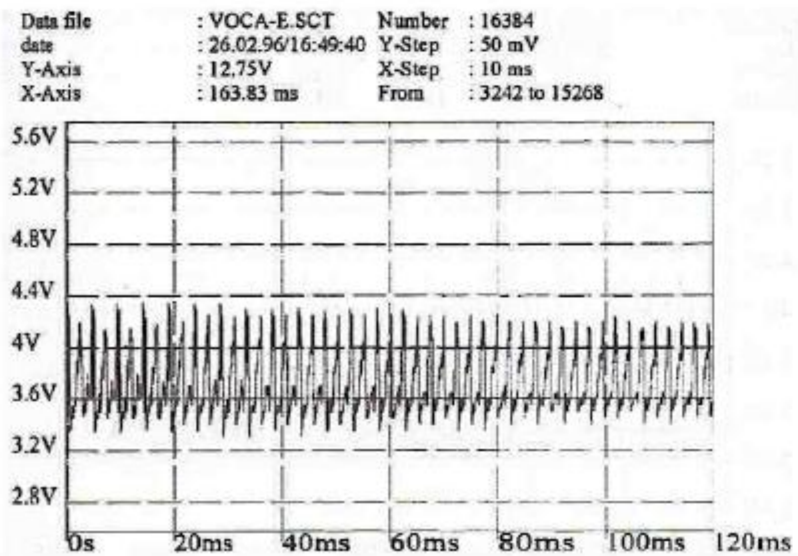
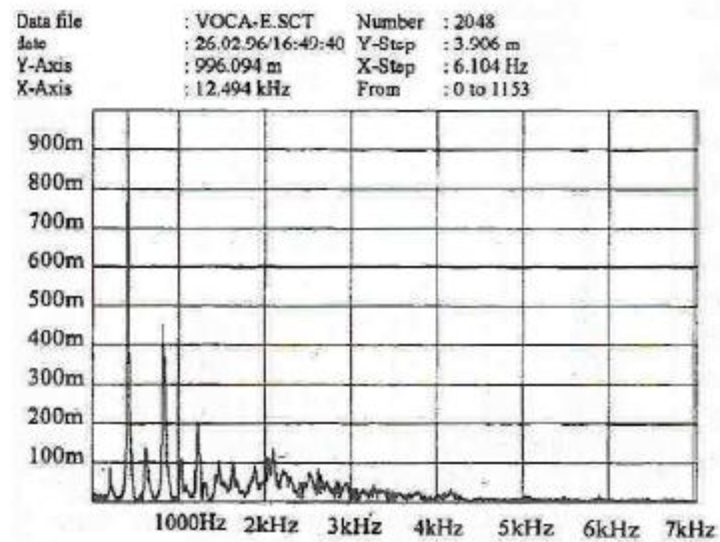
Voice coding: voiced sound

Time- frequency features, vowel e



Signal in time



Signal spectrum (frequency components)

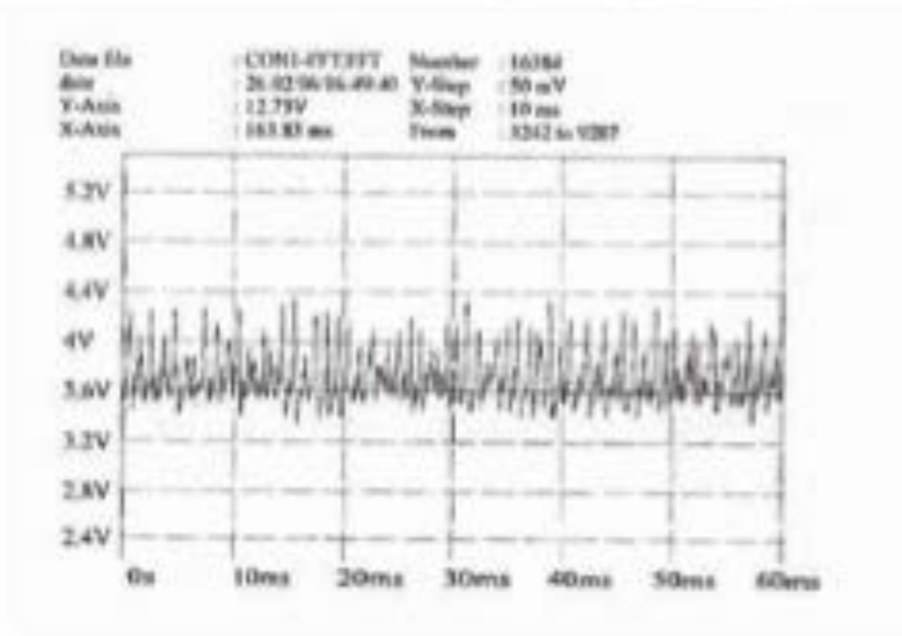
- Sounds produced by the vibrations of the vocal folds
- Features:

  1)Periodic (pitch period); 2) High amplitude; 3) Slow variation of the signal

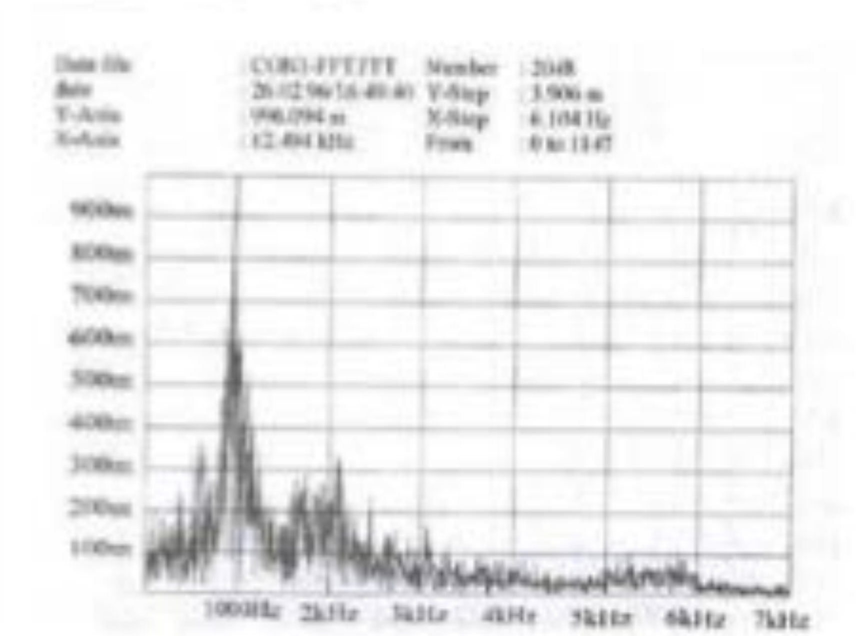
  4) low number of frequencies around which the energy is concentrated (formant frequencies) 5) formant frequencies are low frequencies

Voice coding: voiceless sound

Time- frequency features, consonant f



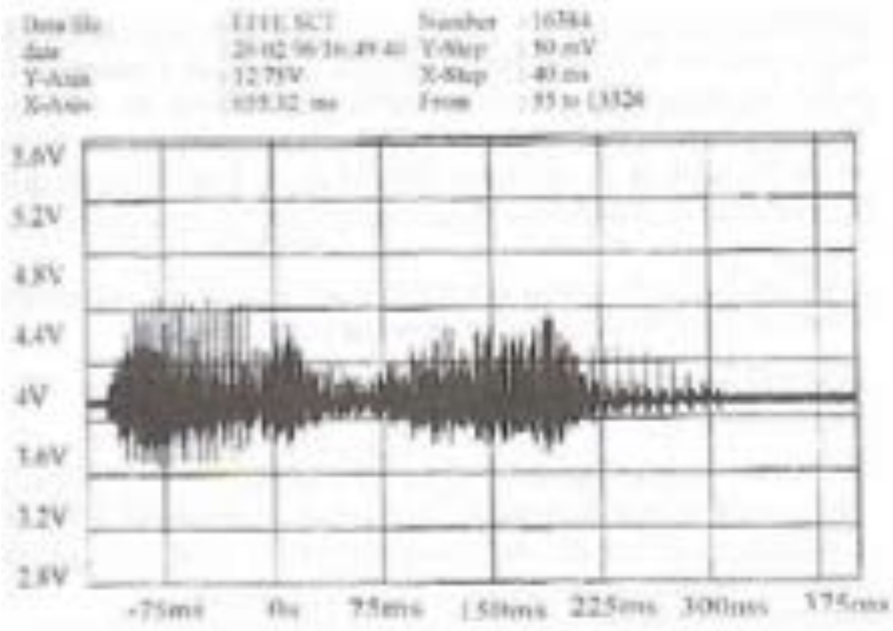
Signal in time

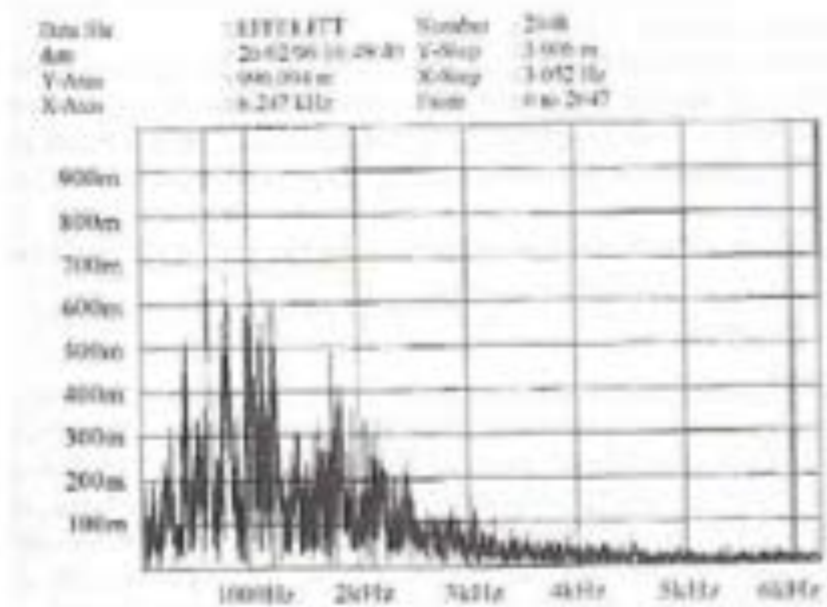


Signal spectrum (frequency components)

- Features: 1)Randomic pattern ; 2) Lower amplitude; 3) Energy concentrated also at higher frequencies.

One word: effe



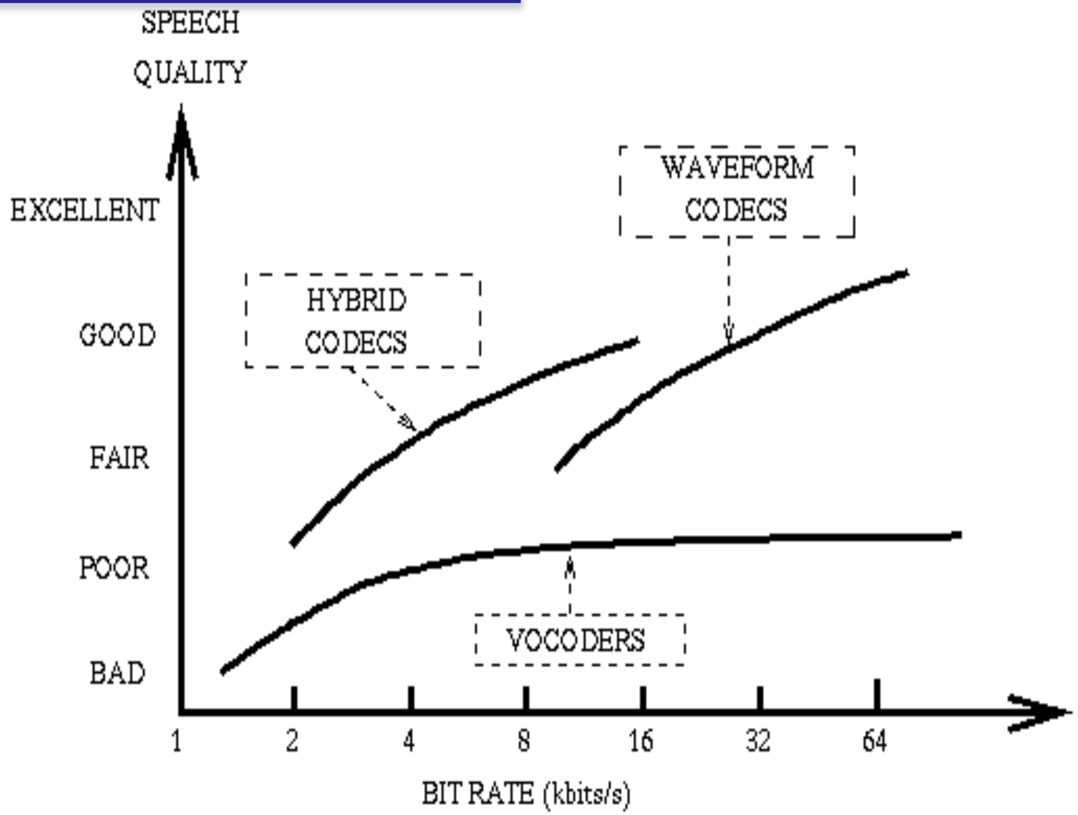


- Vowels and Consonants have different amplitudes.
- The most significant frequency components are located between 300Hz and 3400Hz, with (small) spectral components till 7KHz

Speech signal is translated into a sequence of bits

Mean Opinion Score

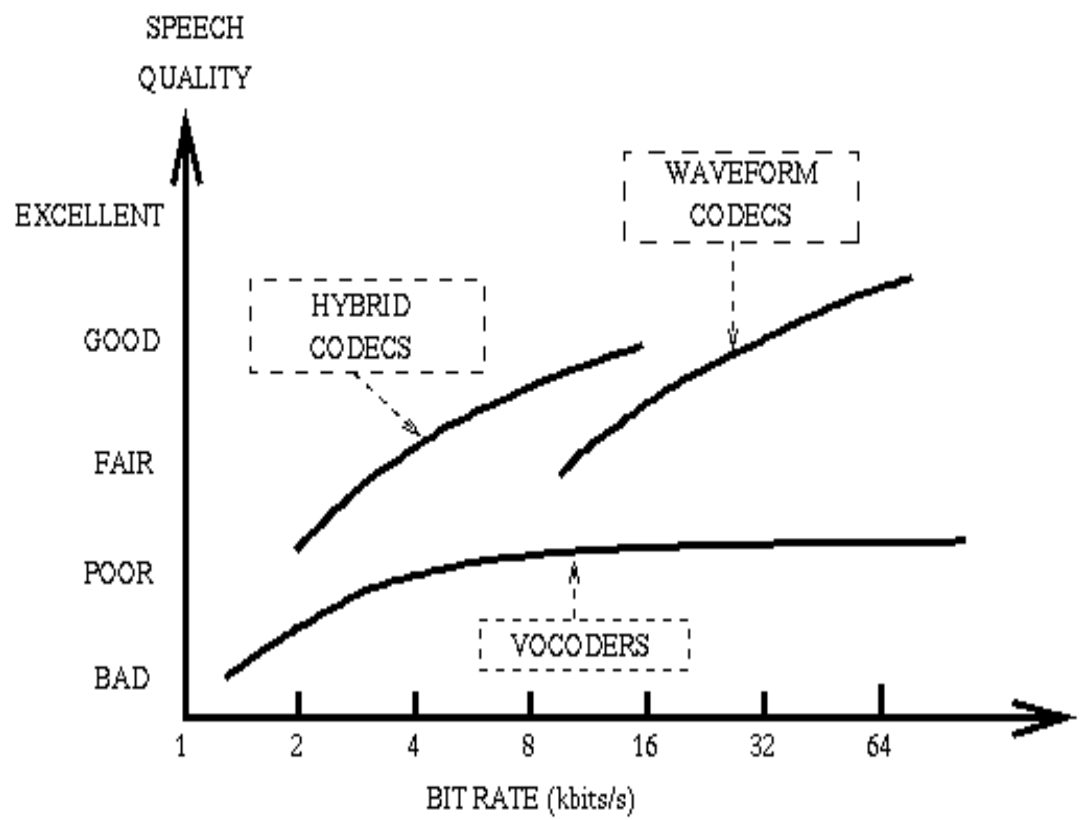
- Waveform codecs
- Source codecs (vocoders)
- Hybrid codecs



Speech signal is translated into a sequence of bits

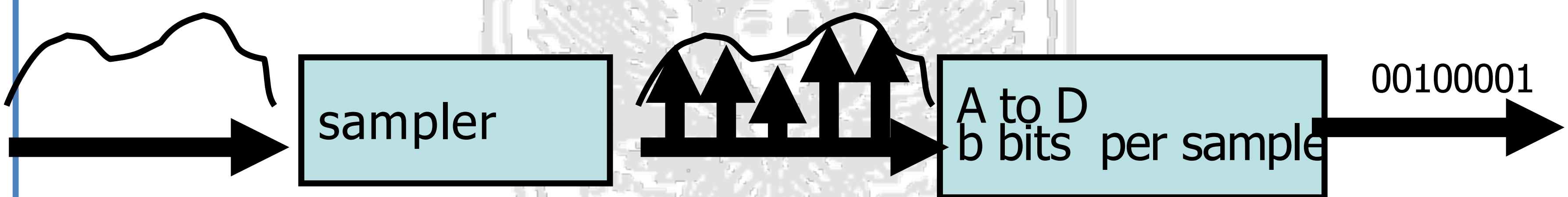
Digitization of an analog signal ←
They make an explicit description of the waveform input (es. PCM)

- Waveform codecs
- Source codecs (vocoders)
- Hybrid codecs



Waveform codecs

- no a priori knowledge of how the signal was generated
- Information needed
  - Signal bandwidth (speech signal< 4 KHz)
  - maximum tolerable quantization noise



high quality, low complexity, low delay (1 sample), robustness to errors and background noise

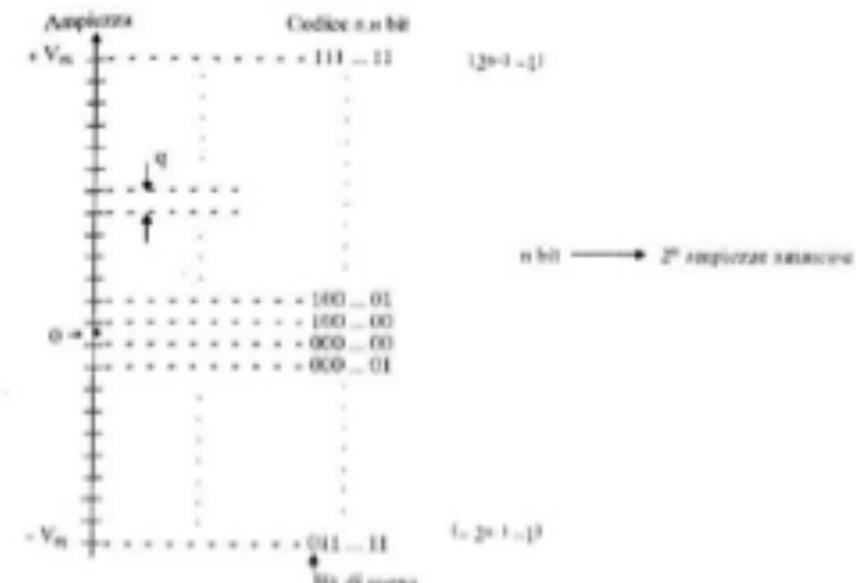
Waveform coding: Pulse Code Modulation (PCM)

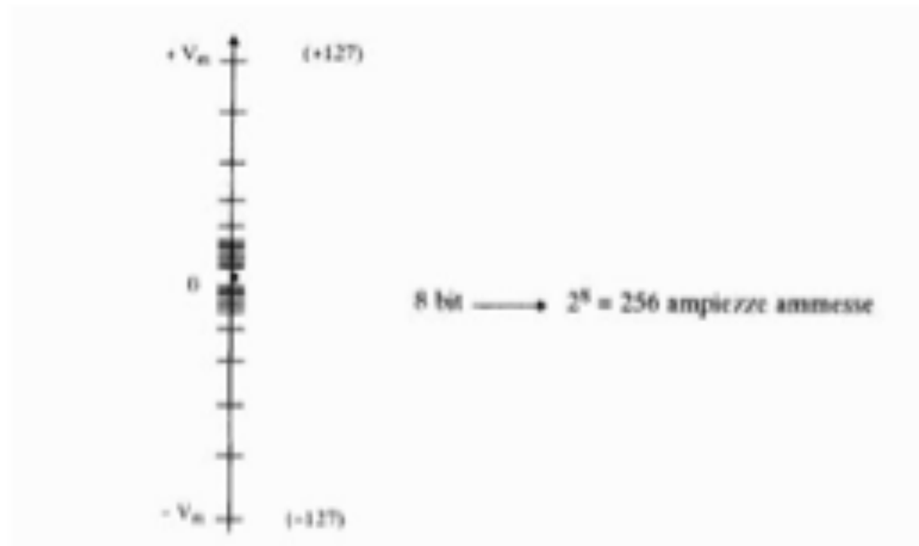
- standardized by ITU in 1960: G.711
- We assume B = 4 kHz, and the sampling frequency Bc = 8 kHz, 8 bit / sample, 64 kb / s
- Two different quantization rules (logarithmic)
  - for America (m-law) and for Europe (A-law)
  - standard conversion rules

Quantization

Uniform quantization

Non - Uniform quantization

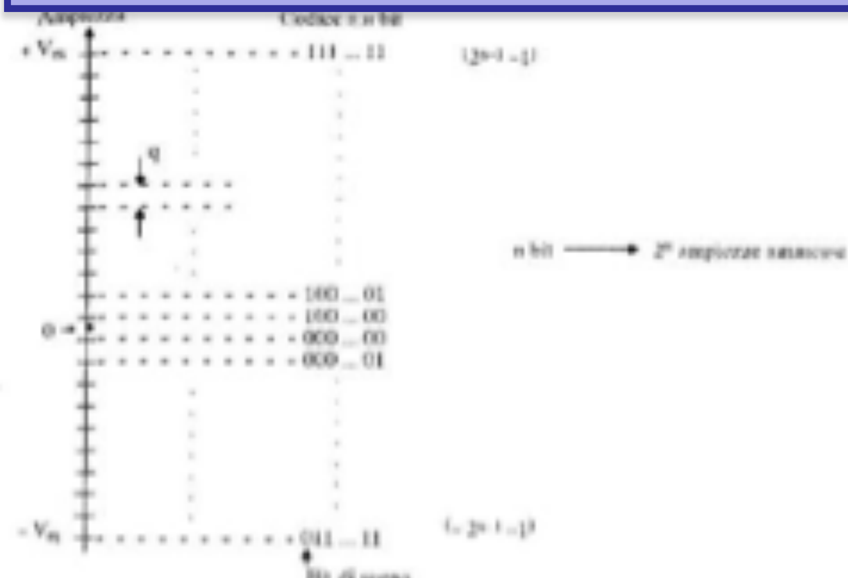




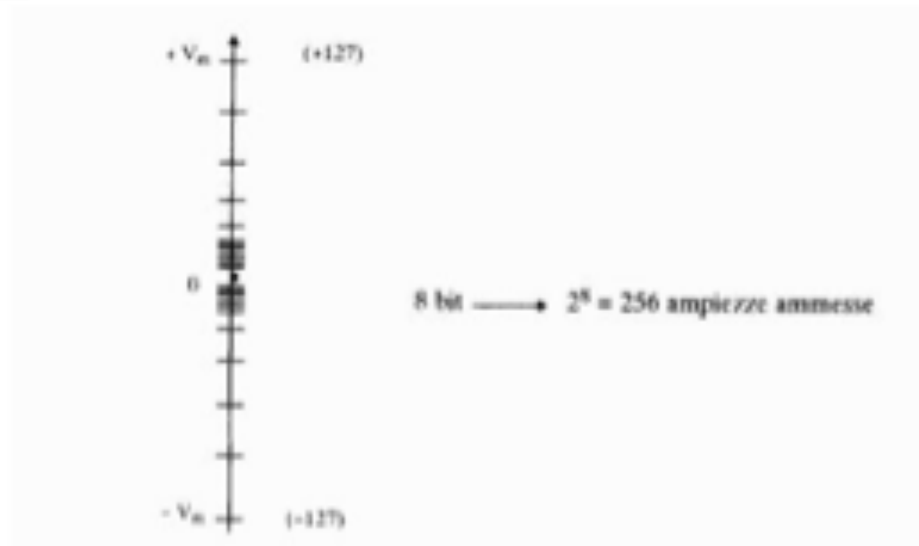
- Quantization error is fixed (<q/2, where q is the quantization step)
- 12 bit per sample are needed to achieve a quantization error low enough also for small values

Quantization

The axis of the amplitudes is divided into equal intervals



Non - Uniform quantization



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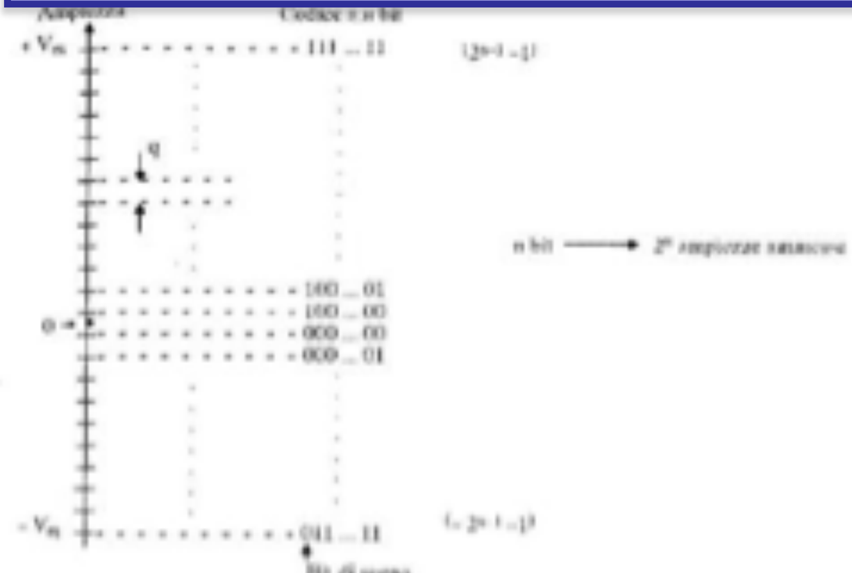
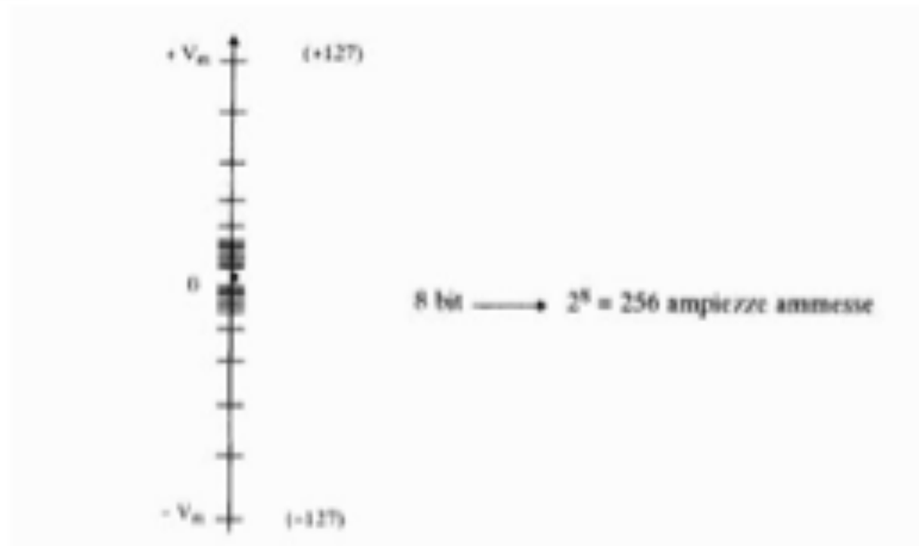
Quantization

The axis of the amplitudes is divided into equal intervals — **Non - Uniform quantization**





- Quantization error is fixed (<q/2, where q is the quantization step)
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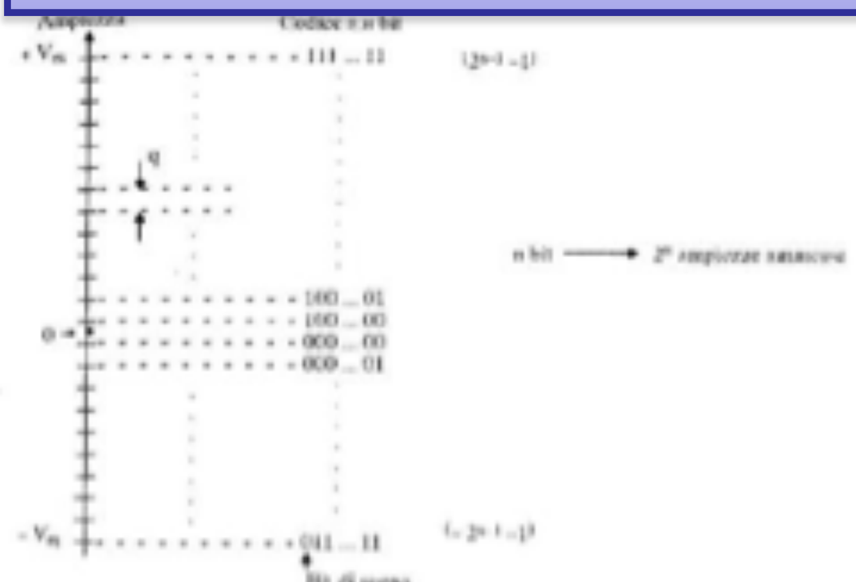
- Many relatively small values
- Higher quantization errors can be tolerated in case of high values
- 8 bits per sample results in excellent perceived quality

Quantization

The axis of the amplitudes is divided into equal intervals



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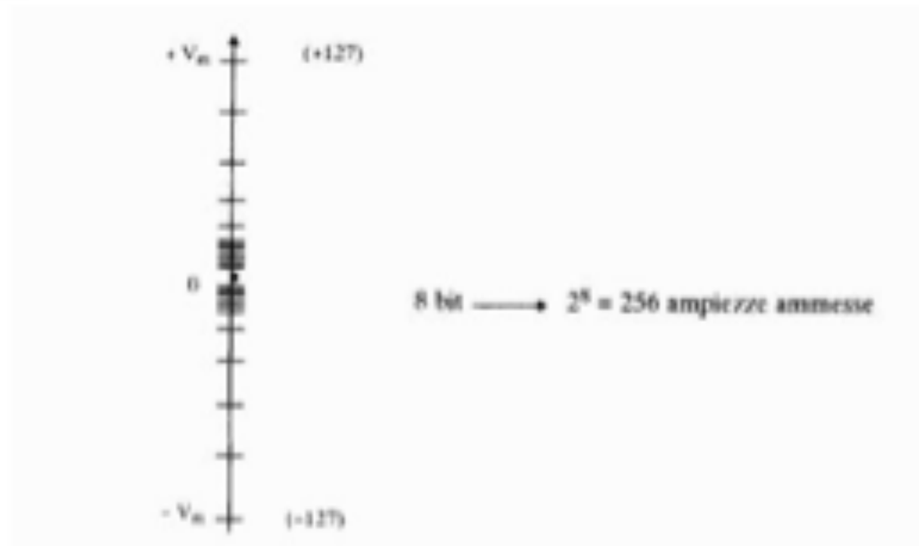
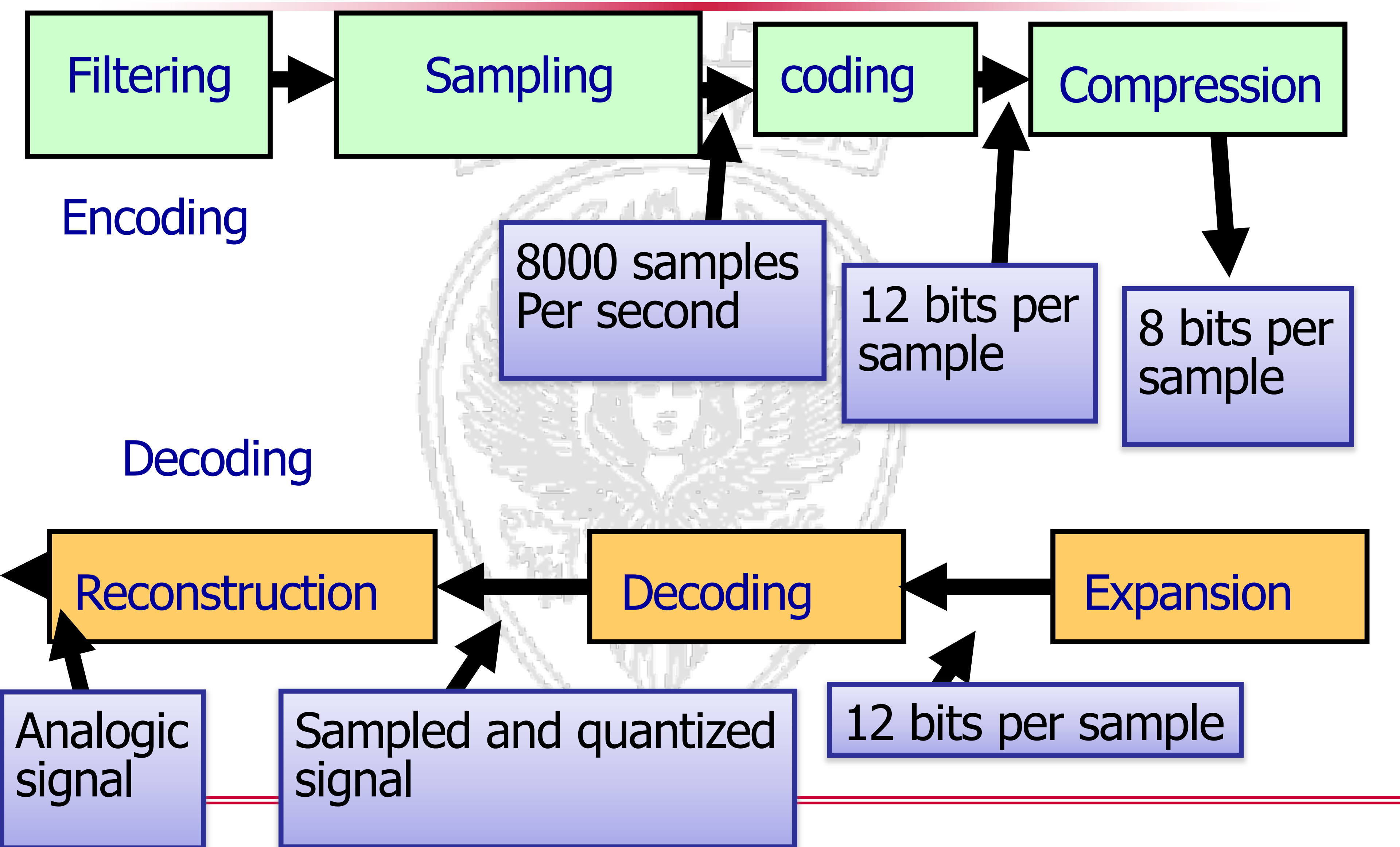


- Many relatively small values
- Higher quantization errors can be tolerated in case of high values
- 8 bits per sample results in excellent perceived quality

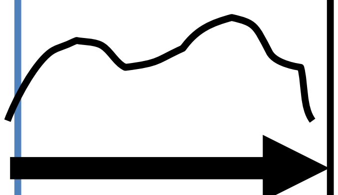
compression

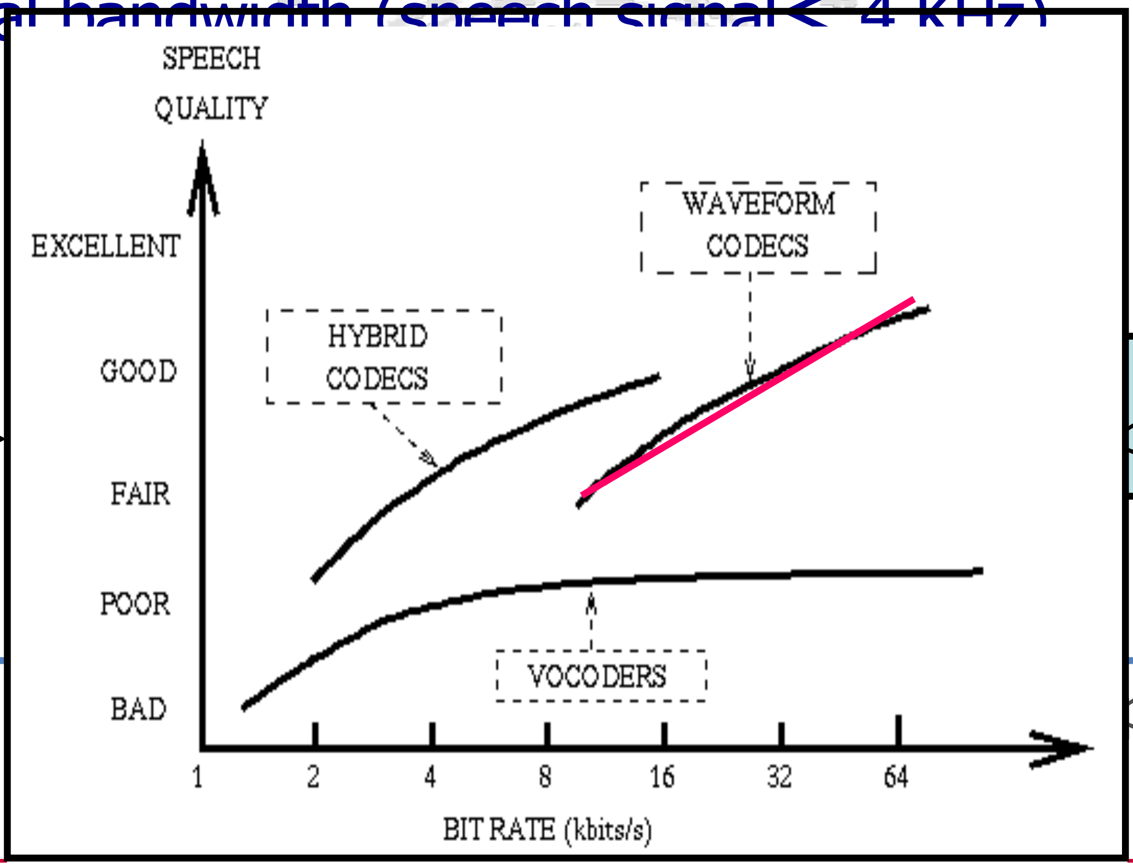
SAPIENZA
UNIVERSITÀ DI ROMA

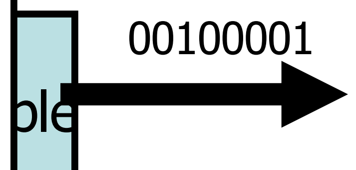
Fasi della codifica/decodifica



- no a priori knowledge of how the signal was generated
- Information needed
  - Signal bandwidth (speech signal < 4 KHz)
  - maxi



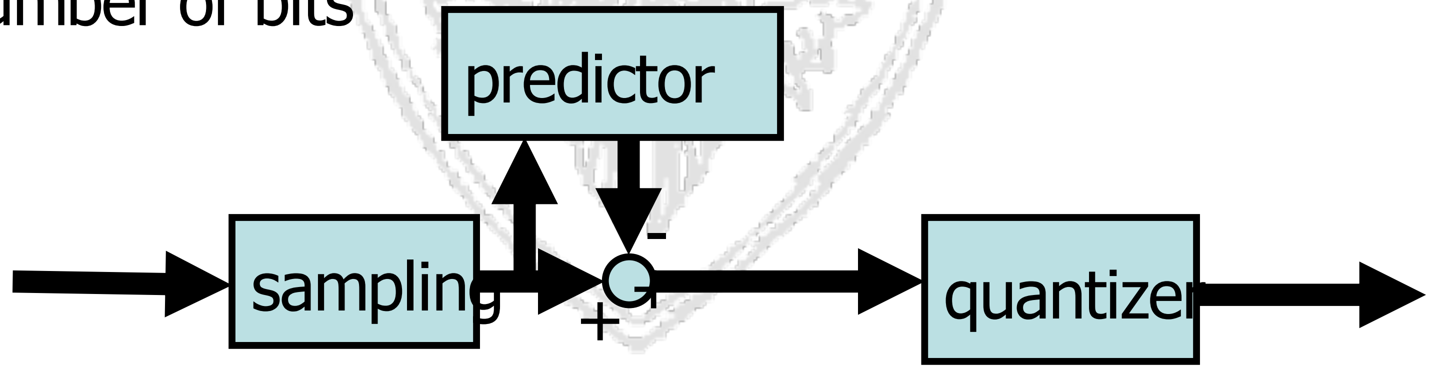




ble),

Differential PCM (DPCM)

- the subsequent voice samples are correlated
- You can use prediction methods for evaluating the next sample known previous
- transmitting only the difference between the predicted value and the actual value
- because of the correlation the variance of the difference is smaller and it is possible to encode it with a smaller number of bits



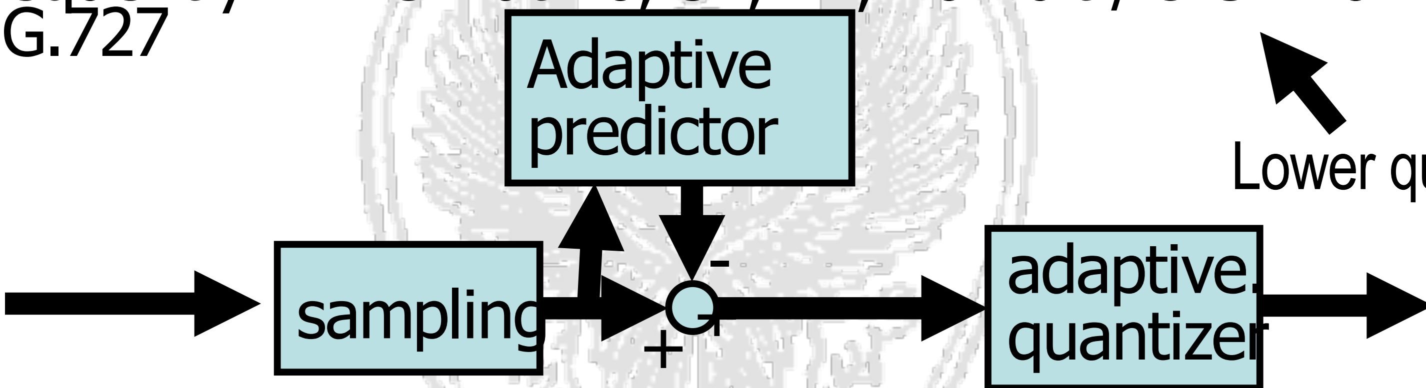
Adaptive DPCM (ADPCM)

- performance improves if the predictor and quantizer are adaptive

Cordless DECT

- standardized in 1980 by ITU ADPCM 32 kbit / s G.721
- subsequently ADPCM at 40, 32, 24, 16-kbit / s G.726 and G.727

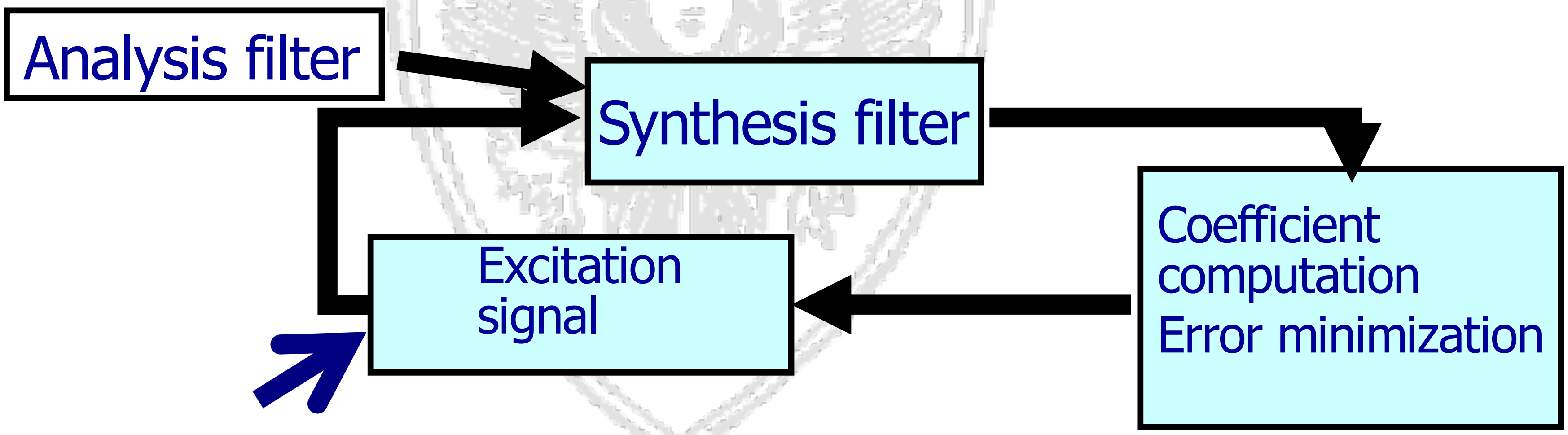
Lower quality



Benefits: Reducing the rate of emission while achieving equal quality (from 64 Kbps to 32 Kbps) 2) enable higher quality given a fixed data rate available per voice channel)

Source codecs (vocoders)

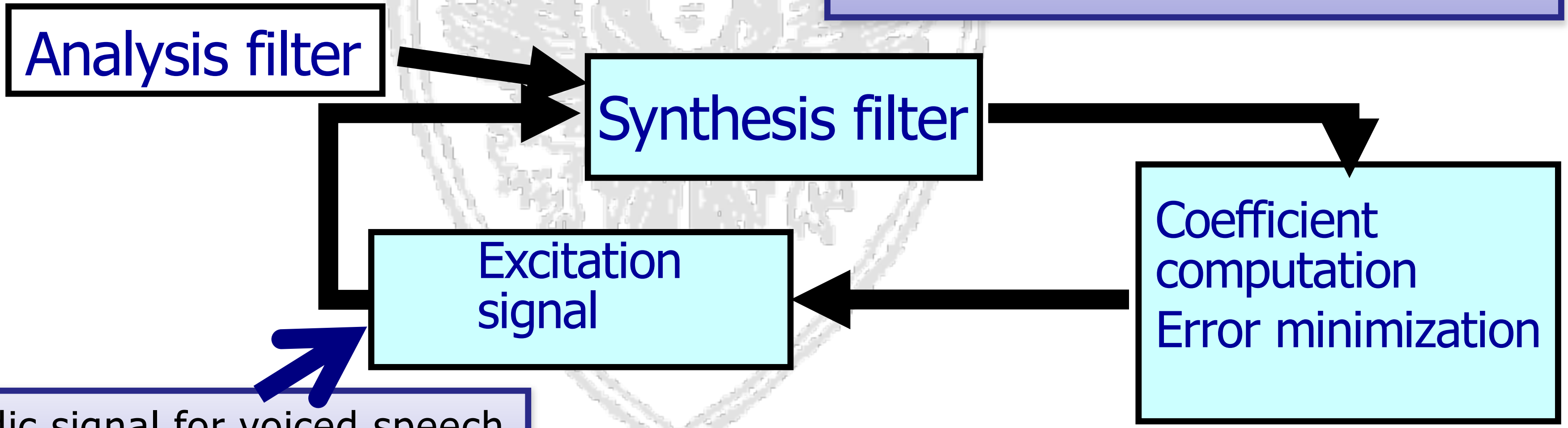
- They are based on models for the generation of the human voice
- models allow us to "remove redundancy" from the vocal segments to obtain an information base sufficient to reproduce the original voice signal (Idea: If we know the structure of the signal little information features will be enough to rebuild it)
- high complexity
- delays on average higher
- sensitive to errors, noise and non-human sounds



Source codecs (vocoders)

- Instead of trying to encode the waveform itself, vocoding techniques try to determine parameters about how the speech signal was created and use these parameters to encode the signal
- To reconstruct the signal, these parameters are fed into a model of the vocal system which outputs a speech signal.
- Filter: Transfer function H(z)=A(z)/B(z)

Example: Linear Predictive Coding(LPC)



Periodic signal for voiced speech
Noise for voiceless speech

Mean square error

Linear Vocoder (LPC)

- They encode the parameters of the synthesis filter and the excitation sequence
- in decoding a synthesizer uses the received parameters to reproduce the signal
- **The voice sample is approximated by a linear combination of a number of past samples**

- high delays: segmentation, analysis, synthesis
- quality intelligible but not natural (limits in the model + problems with background noise)
- low bit rate: <2.4 kbit / s

Main voice coding

Coding	Year	Bit rate (kbit/s)	Frame size (ms)	Look ahead (ms)
G.711 PCM	1972	64	0.125	0
G.726 ADPCM	1990	32	1	0
G.722 Subband ADPCM	1988	48-64	0.125	1.5
G.728 LD-CELP	1992-94	16	0.625	0
G.729 CS-ACELP	1995	8	10	5
G.723.1 MP-MLQ	1995	6.3	30	7.5
G.723.1 ACELP	1996	5.3	30	5
RPE-LTP (GSM)	1987	13	20	0

Codebook Excited Linear prediction

LTP= Long term prediction

Hybrid

Regular pulse excitation-residual signal is undersampled

The sequence of departure from which the decoder must start to rebuild the speech signal is not a pseudorandom sequence but is representative of the "real signal"

Codebook Excited Linear Prediction

- Tries to overcome the synthetic sound of vocoders by allowing a wide variety of excitation signals, which are all captured in the CELP codebook.
- To determine which excitation signal to use, the coder performs an exhaustive search.
  - For each entry in the codebook, the resulting speech signal is synthesised and the entry which created the smallest error is chosen.
- The excitation signal is encoded by the index of the corresponding entry (Vector Quantisation)
- CELP techniques allow bit rates of even 4.8 kbps.

Main voice coding

Codebook Excited Linear prediction

LTP= Long term prediction

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Hybrid

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3.5 – Procedures

Procedures

- O. Bertazioli, L. Favalli, *GSM-GPRS*, Hoepli Informatica 2002
  Capitolo 11

GSM procedures

- Network Access
- Mobility
- Call Set Up
- Handover
- Paging

IMSI attach and Location Update

IMSI attach

- When a MS is switched ON:
  - **Cell selection**: the MS selects the BTS to which tune to
  - **Registration** (Location Update procedure): the MS notifies the MSC of its presence in the Location Area

Cell Selection

- The MS scans all RF carriers operating in the cell:
  - Scans c0 carrier over which the BCCH is transmitted
  - Such carriers are transmitted ad higher power than other carriers (dummy bursts are used when necessary), and frequency hopping is disabled
- The MS connects to the RF carrier from which the strongest signal is received
- Through the FCCH channel the MS synchronizes to the BTS carrier
- Through the SCH the MS synchronizes to the slot and frame and receives the BSIC – Base Station Identity Code
- The MS can now decode the BCCH, which includes
  - ✓LAC (Location Area Code)
  - ✓CGI (Cell Glocal Identity)
  - ✓MCC (Mobile Country Code)
  - ✓MNC (Mobile Network Code)

Registration

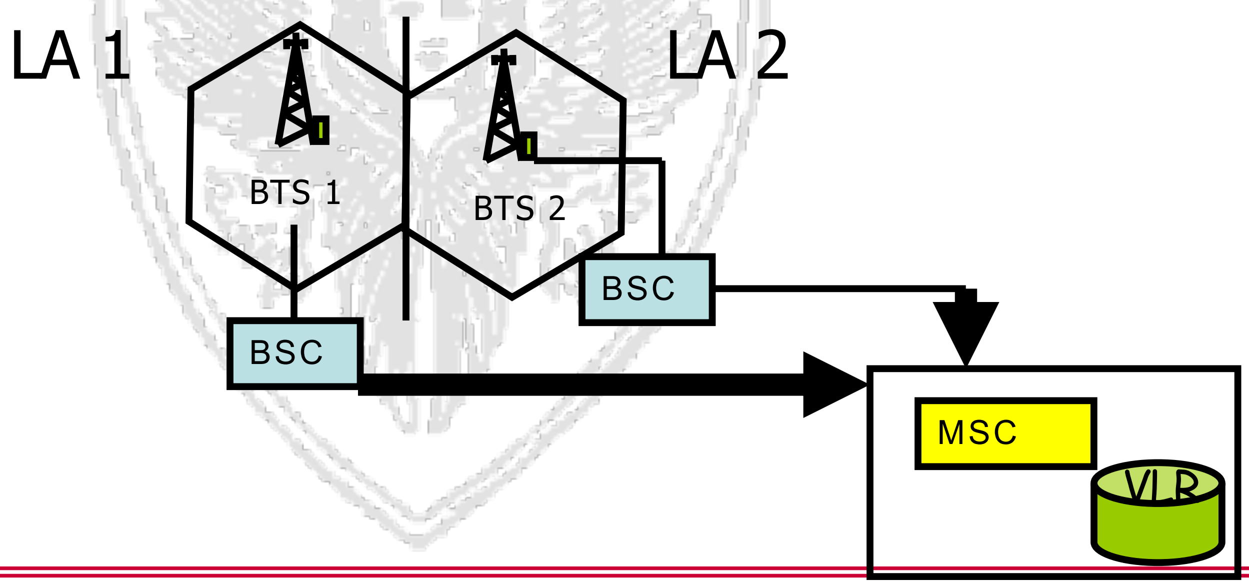
Two cases are possible, based on the **received LAI**:

1)**It is the same of that stored in the SIM** (which happens when the phone is turned off and on in the same LA). The ***IMSI attach*** procedure is invoked, with which the MS activates its IMSI stored in the current VLR (it means the MS was previously registered with the VLR, and that the detached flag was set when the MS was switched off – paging is not performed towards detached users)

1)**No LAI stored, o received LAI different from the stored one** (which happens when the phone is turned off and on in different LAs). The ***Location Update*** procedure is invoked.

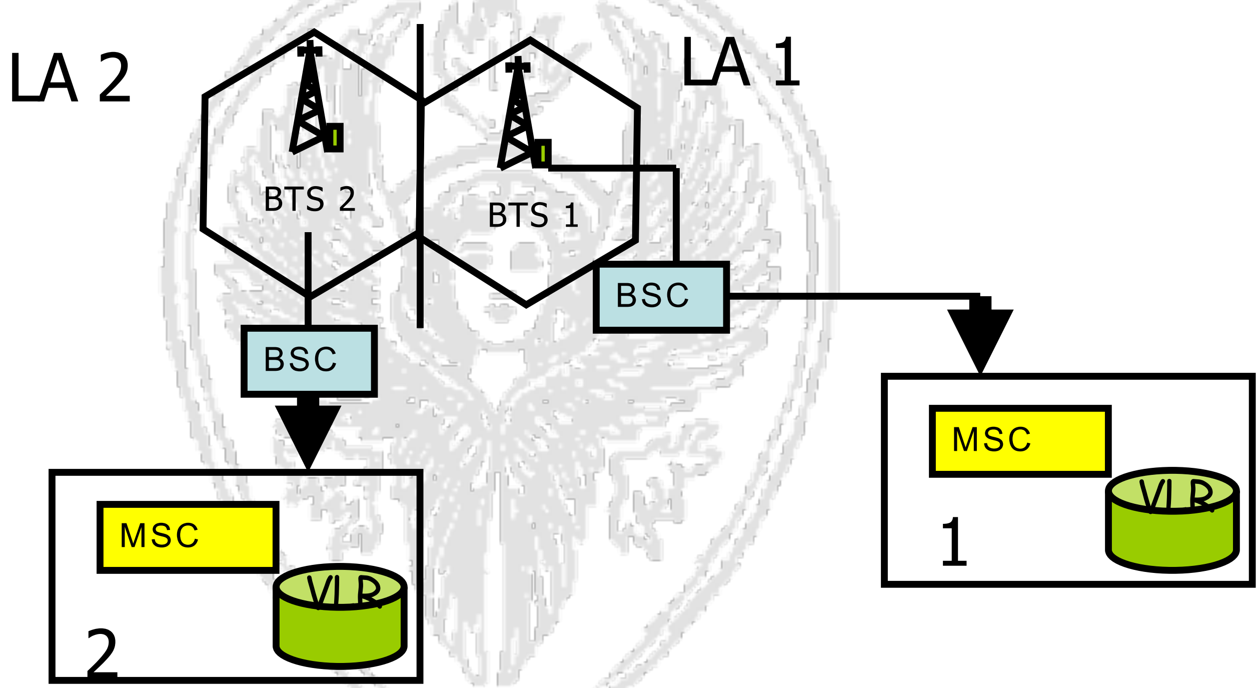
Location Update (1)

- When is it performed?
  - When a MS is switched on (if needed);
  - Periodically (e.g. every 30 min). If the periodic location update is not received, the VLR flags the user as detached -- *implicit detach*;
  - When the Location Area changes due to MS movements (roaming);
- Two types of Location Update:
  - Two LAs of the same MSC/VLR (the simplest case)



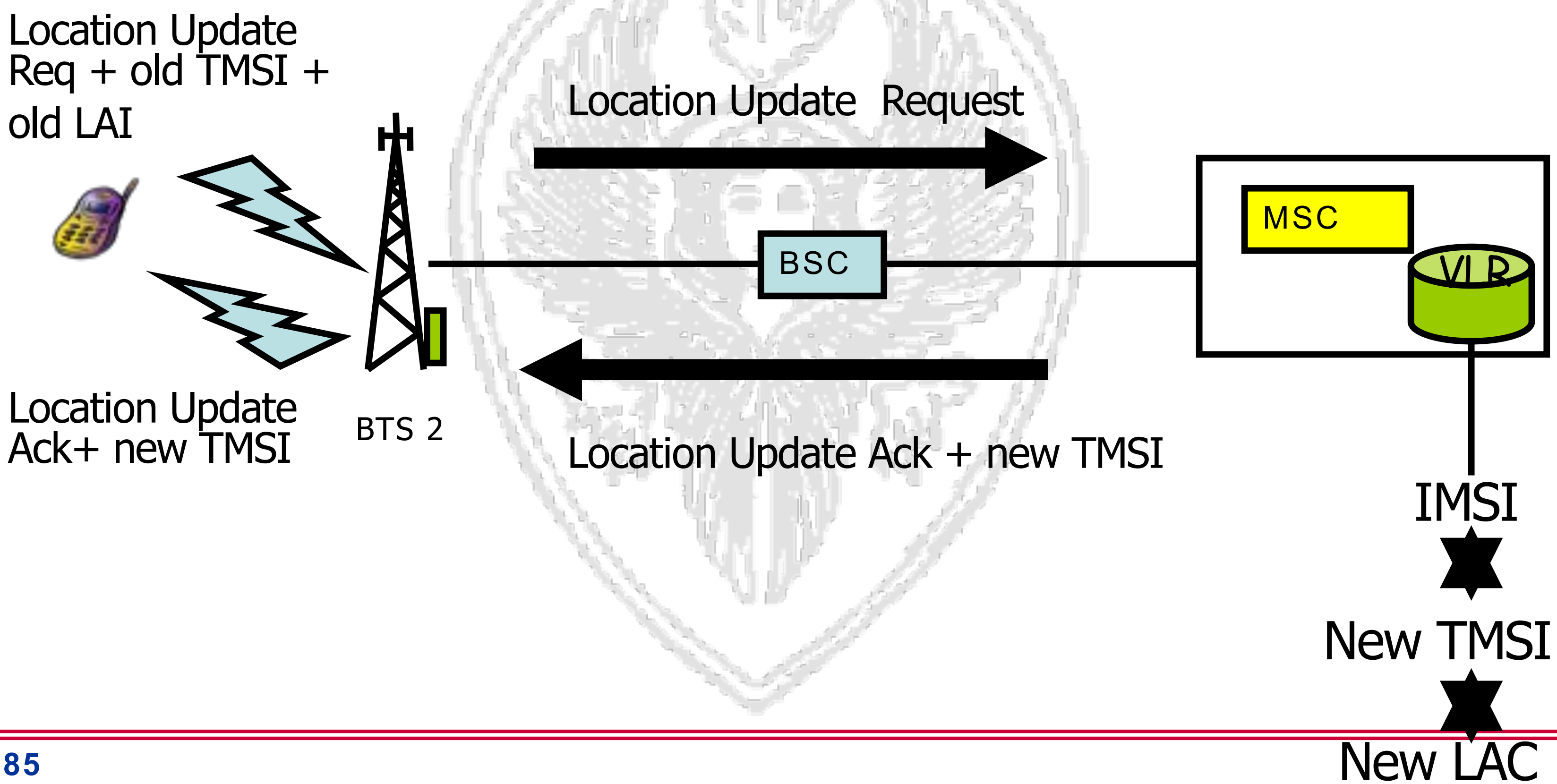
Location Update (2)

- Roaming between LAs of different MSC/VLRs

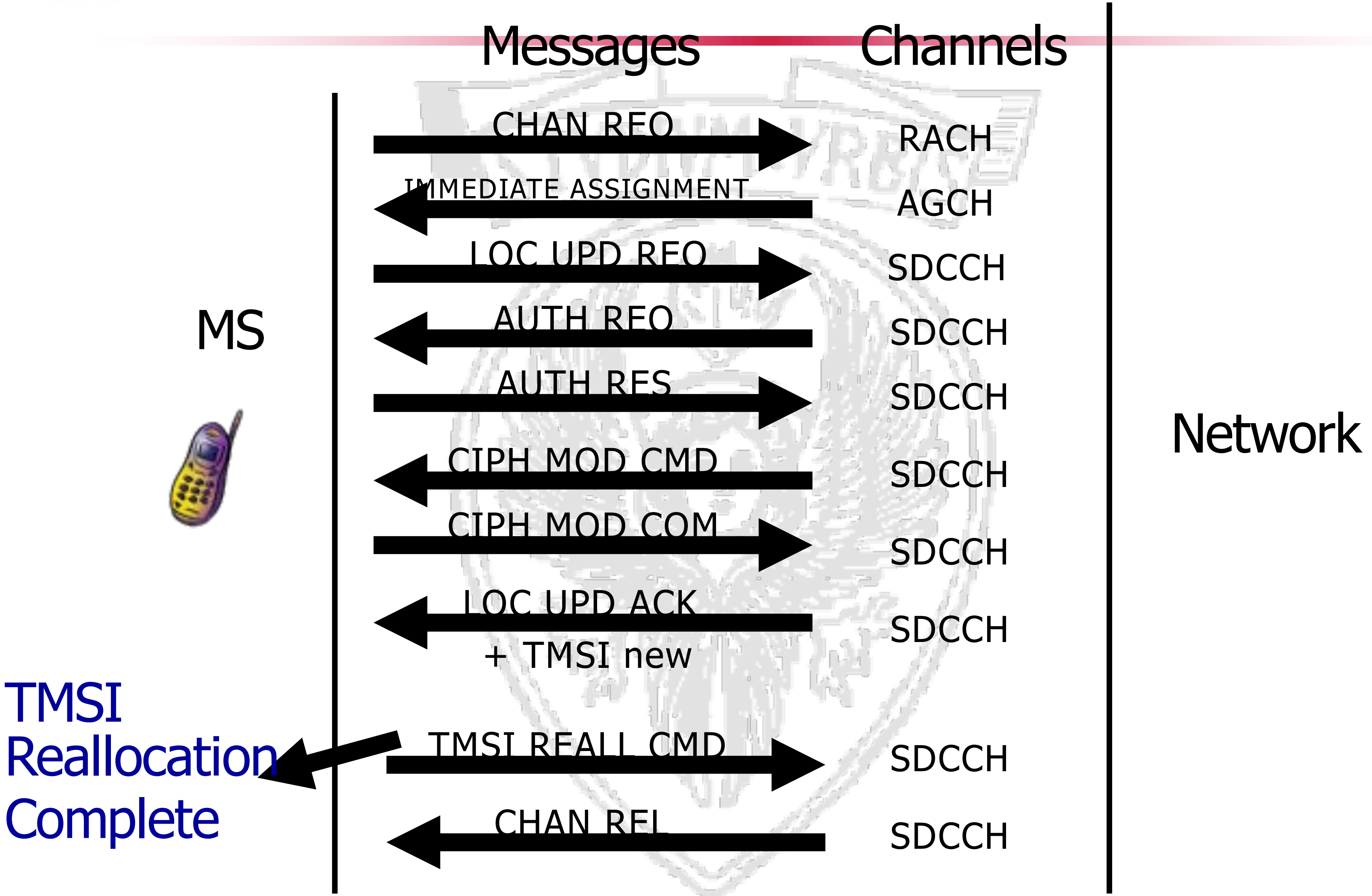


Location Update - Intra MSC

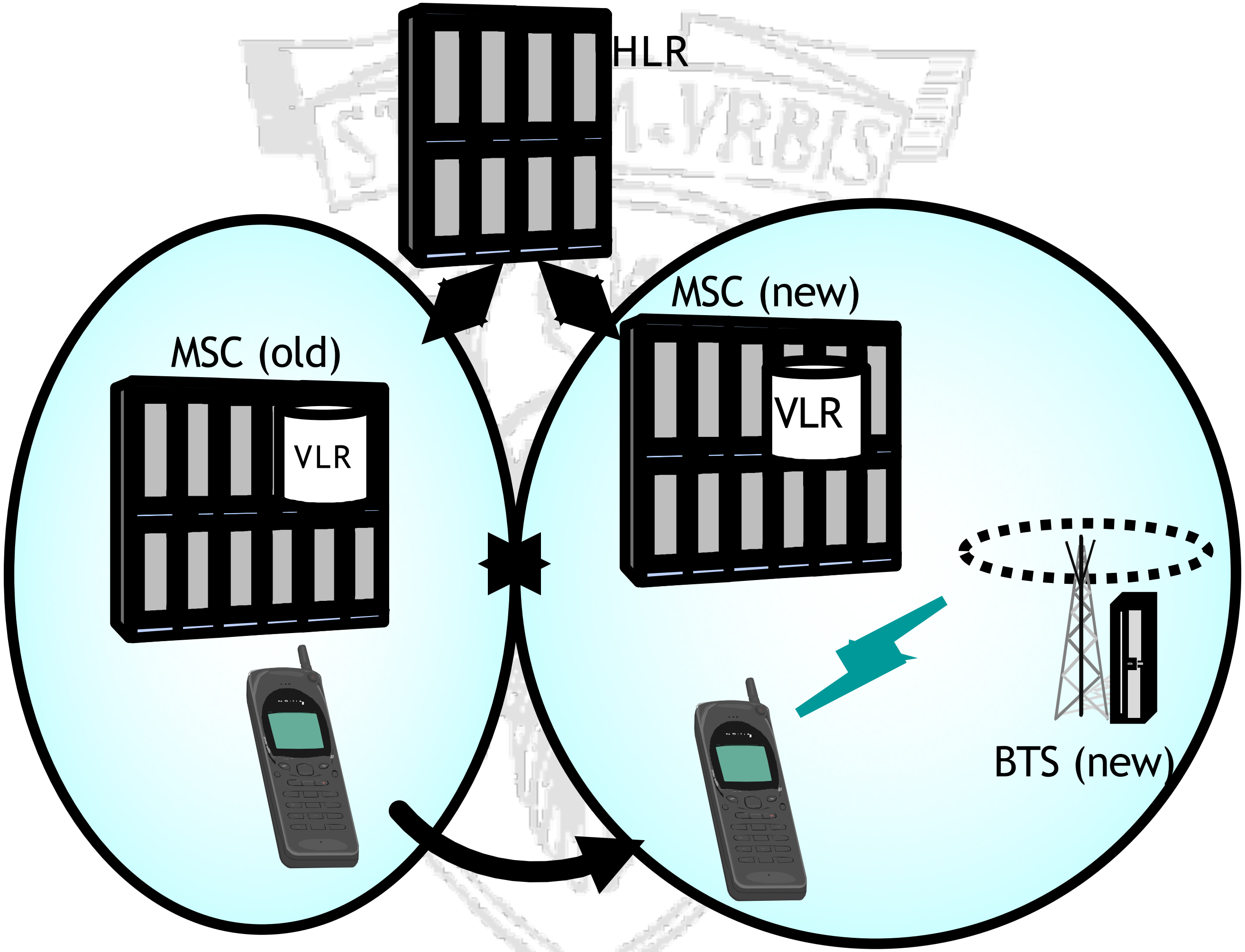
The System Information Message sent over the BCCH contains the location area identifier (LAI). Once tuned to a new BTS, the MS thus can determine if a location update is needed.



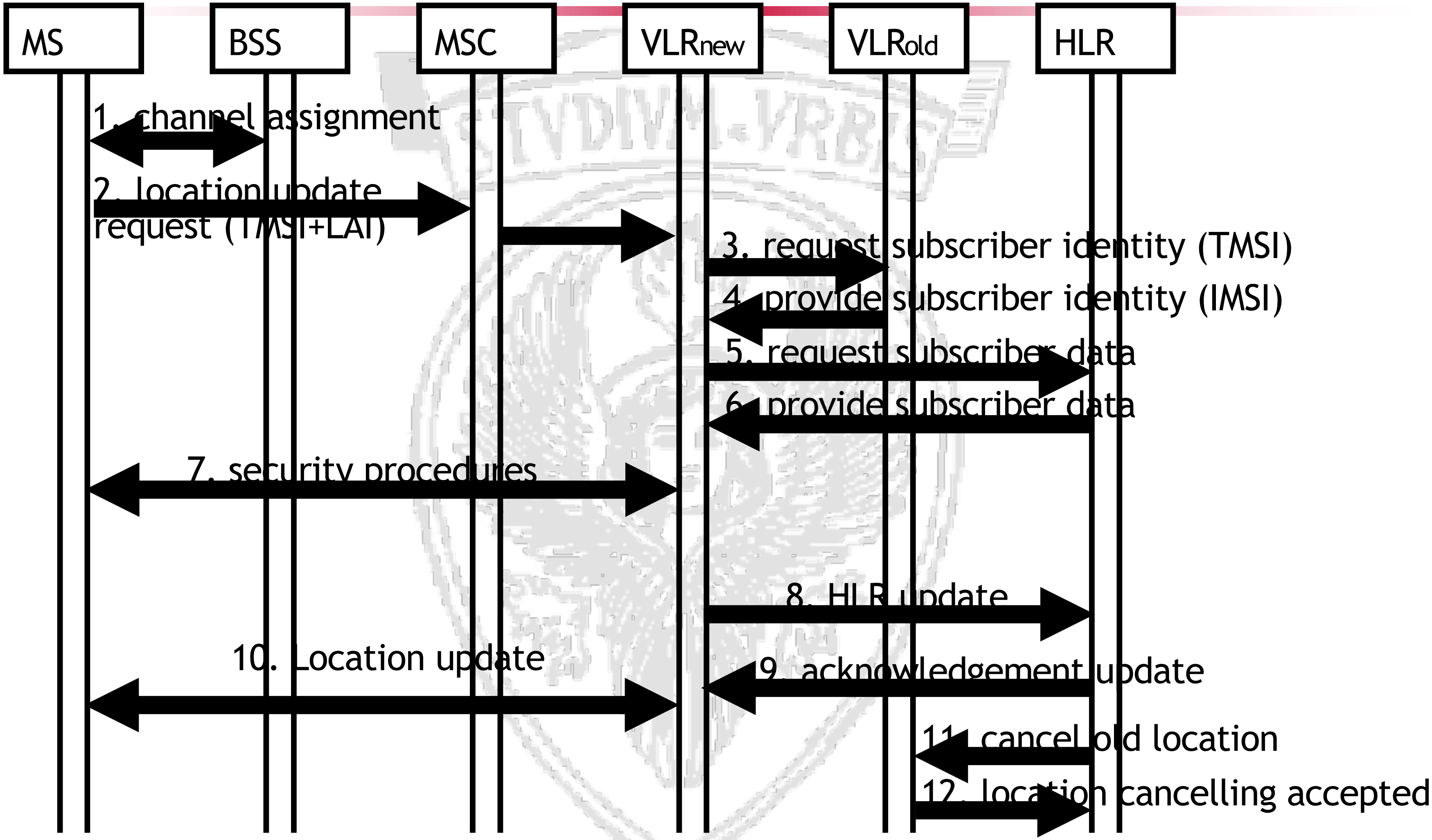
Location Update - Intra MSC



Location Update inter MSC

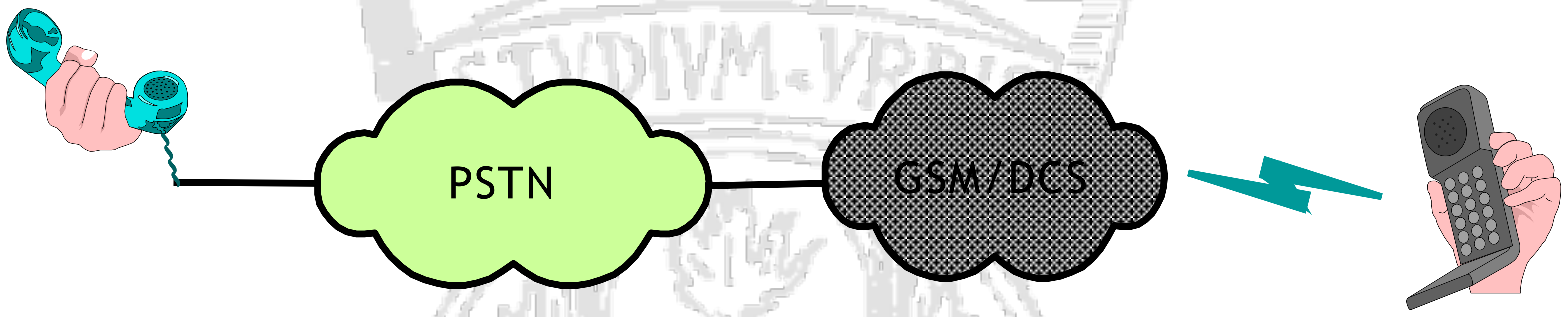


Location Update inter MSC



Call Set Up

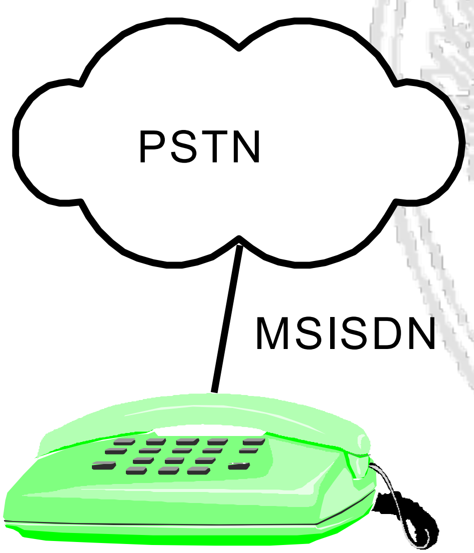
Call originated from PSTN



- Setting up a call terminated on a mobile user is more involved that setting up calls between PSTN users

Call Set-up Step by Step (1)

A The PSTN/ISDN user dials the Mobile Subscriber International ISDN Number (MSISDN) of the user she wants to call



MSISDN: +39 347 6527268

39 = Country Code (Italy)

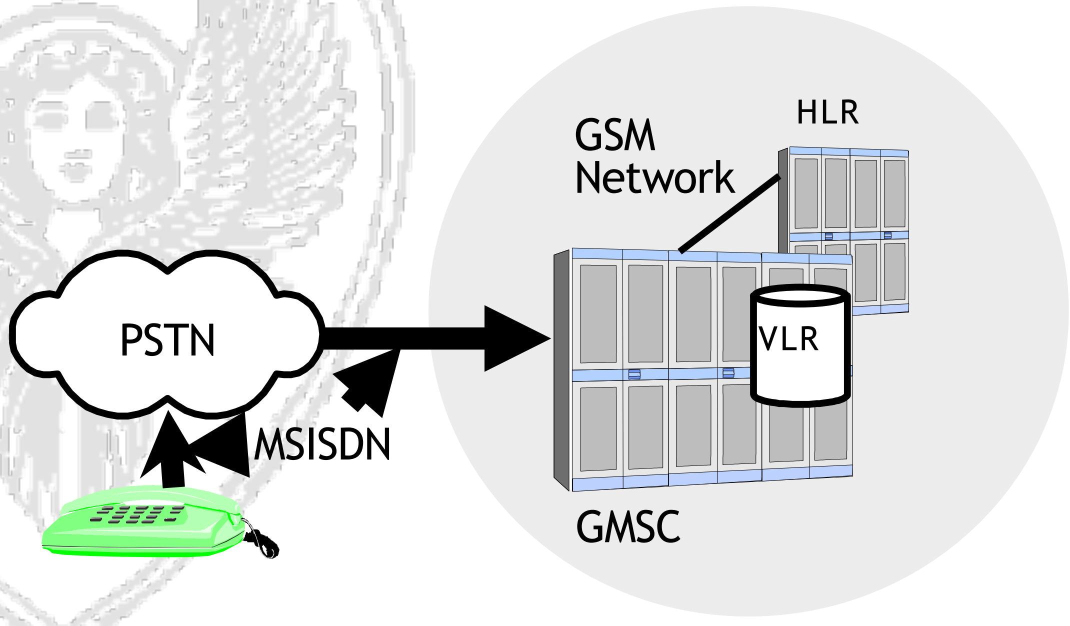
347 = National Destination code

6527268 = Subscriber Number

Call Set-up Step by Step (2)

B The dialled number is analysed by the PSTN/ISDN network, which routes the call to the GMSC of the PLMN of the called user by making use of the National Destination Code (NDC)

C The GMSC receives the message requesting to set-up a call through the SS7 network, which contains the MSISDN of the user called

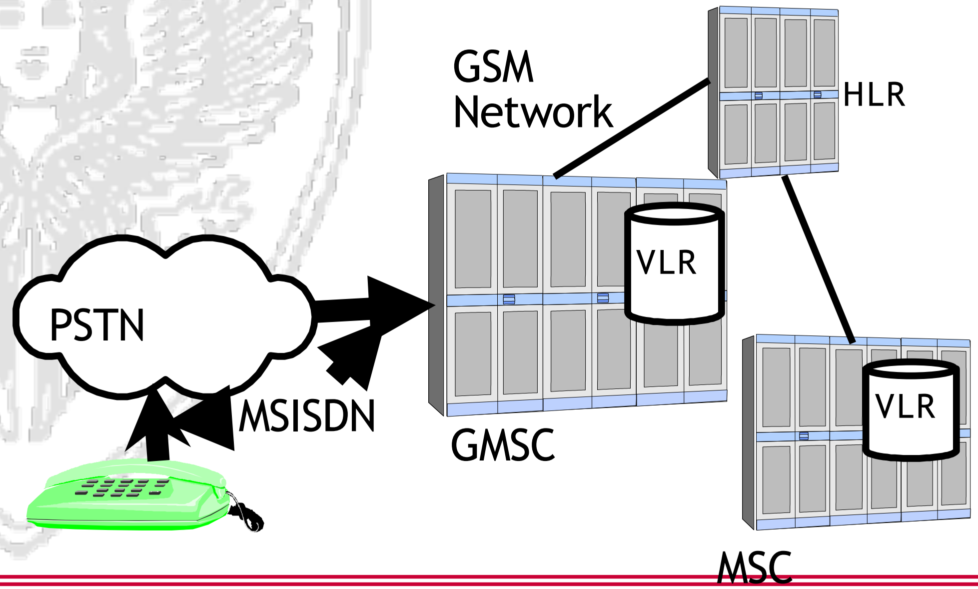


Call Set-up Step by Step (3)

D The GMSC identifies the HLR containing the data of the called user (it is not aware of the position of the MS!!)

E The GMSC sends a message requiring to "send routing information" to the HLR

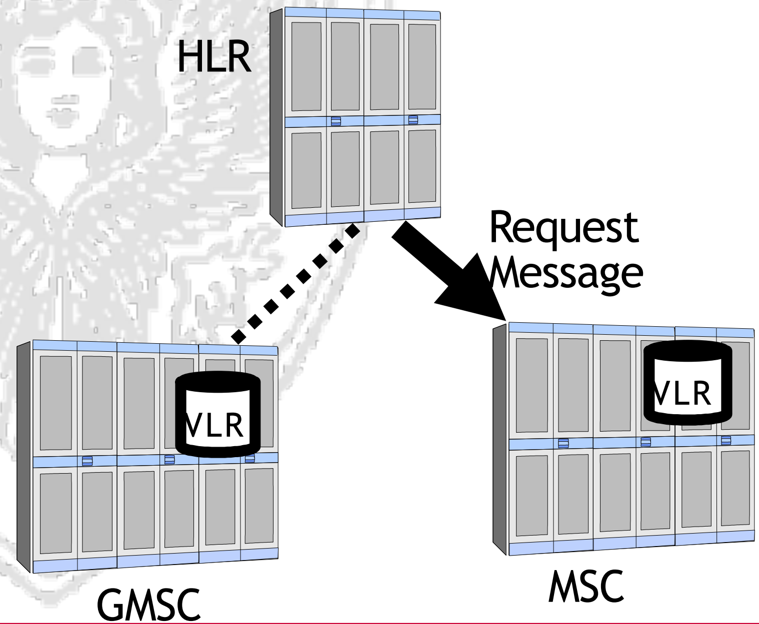
F The HLR identifies the address of the VLR in which the called MS is currently registered



Call Set-up Step by Step (4)

G The HLR sends a "provide roaming number" message to the MSC/VLR

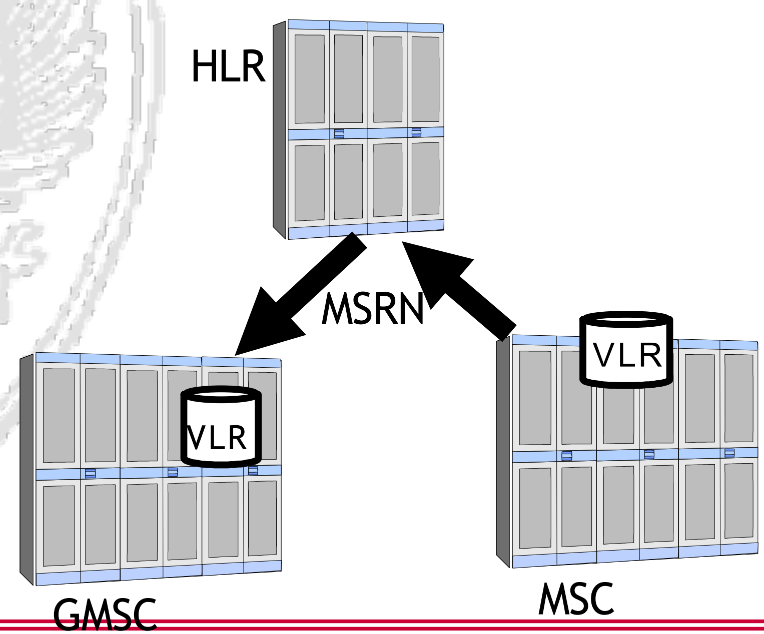
H The MSC/VLR temporarily allocates a Mobile Station Roaming Number (MSRN) to be used for the call



Call Set-up Step by Step (5)

I The MSRN is forwarded by the MSC to the HLR

J The GMSC routes the call towards the MSC/VLR of the LA in which the MS is currently located



Call Set-up Step by Step (6)

K The MSC/VLR activates the **paging** procedure:
  – It identifies the currently-visited LA thanks to the IMSI
  – It sends a paging command to all BSC of the location area

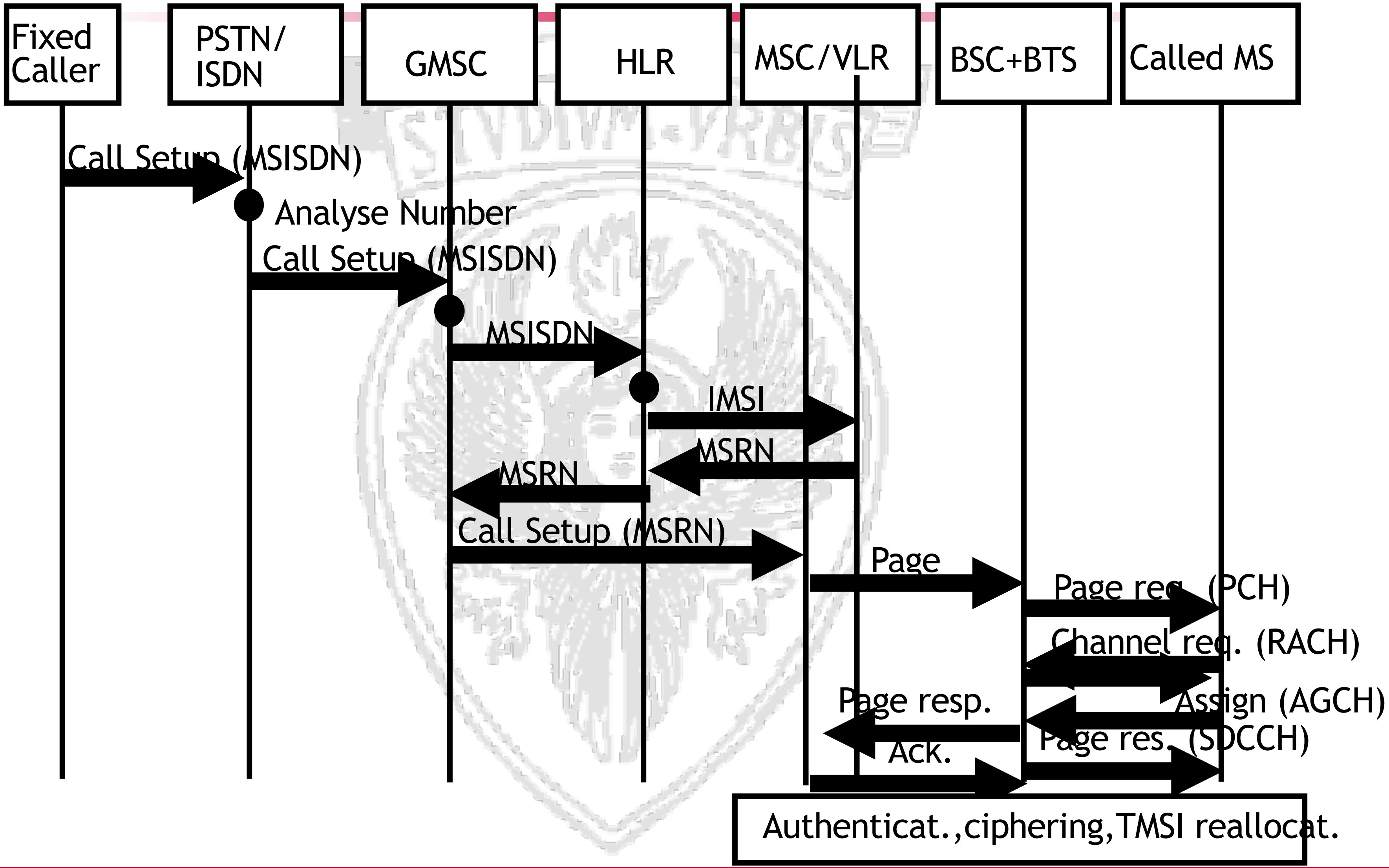
L BSC requires the BTSs to send the paging message destined to the MS over the paging channel (PCH) -- this message contains the TMSI assigned to the MS

M The MS replies to the paging message by requiring a Stand alone Dedicated Control CHannel (SDCCH) through the Random Access CHannel (RACH)

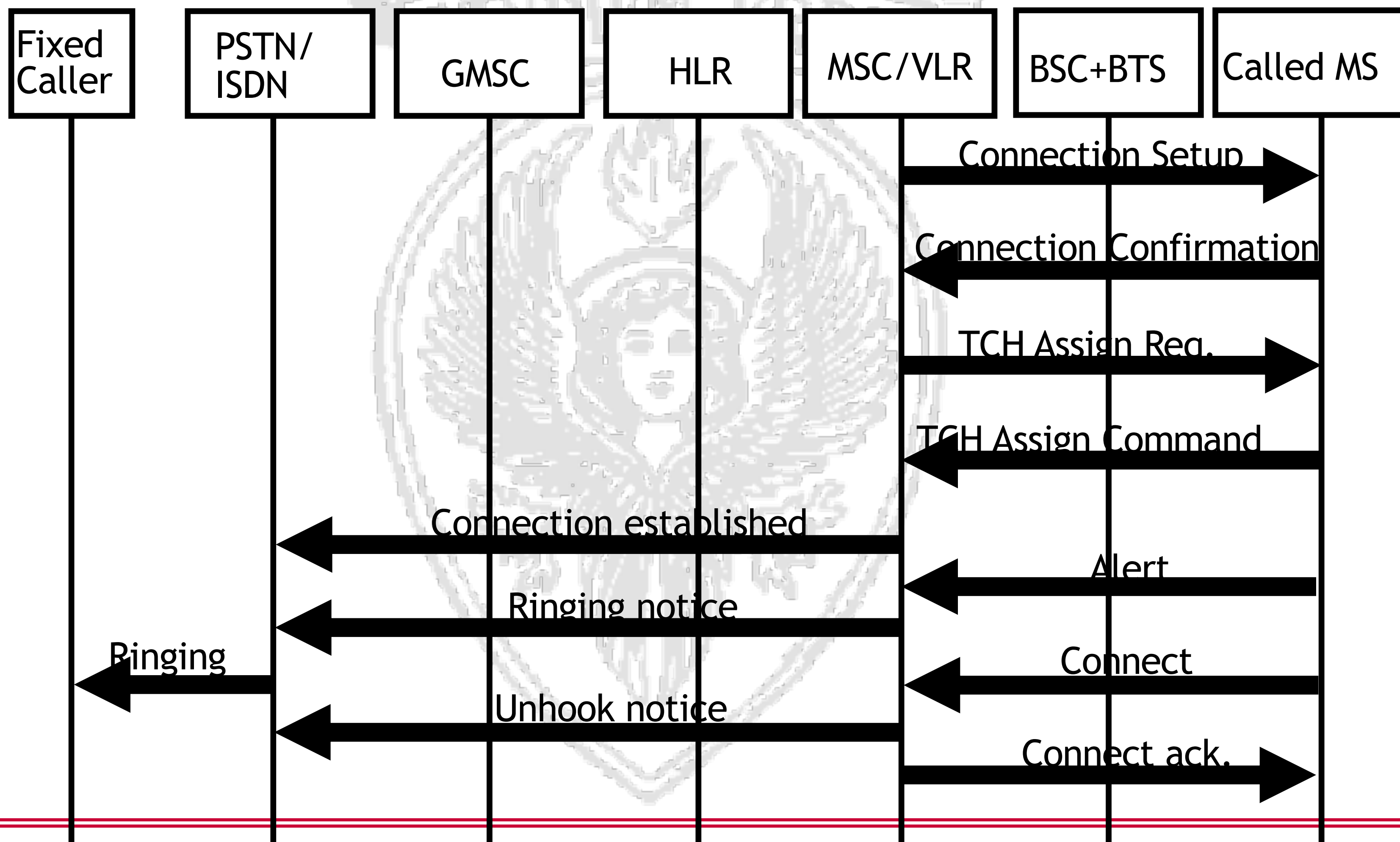
Call Set-up Step by Step (7)

- N The MSC/VLR activates the authentication and the ciphering procedures
- P A traffic channel (TCH) is allocated for the communication
- Q The MSC/VLR notifies the caller that the called phone is ringing
- R The called user answers the call
- S The connection between the two users is established

Summary of the Call Set-up Steps (1)



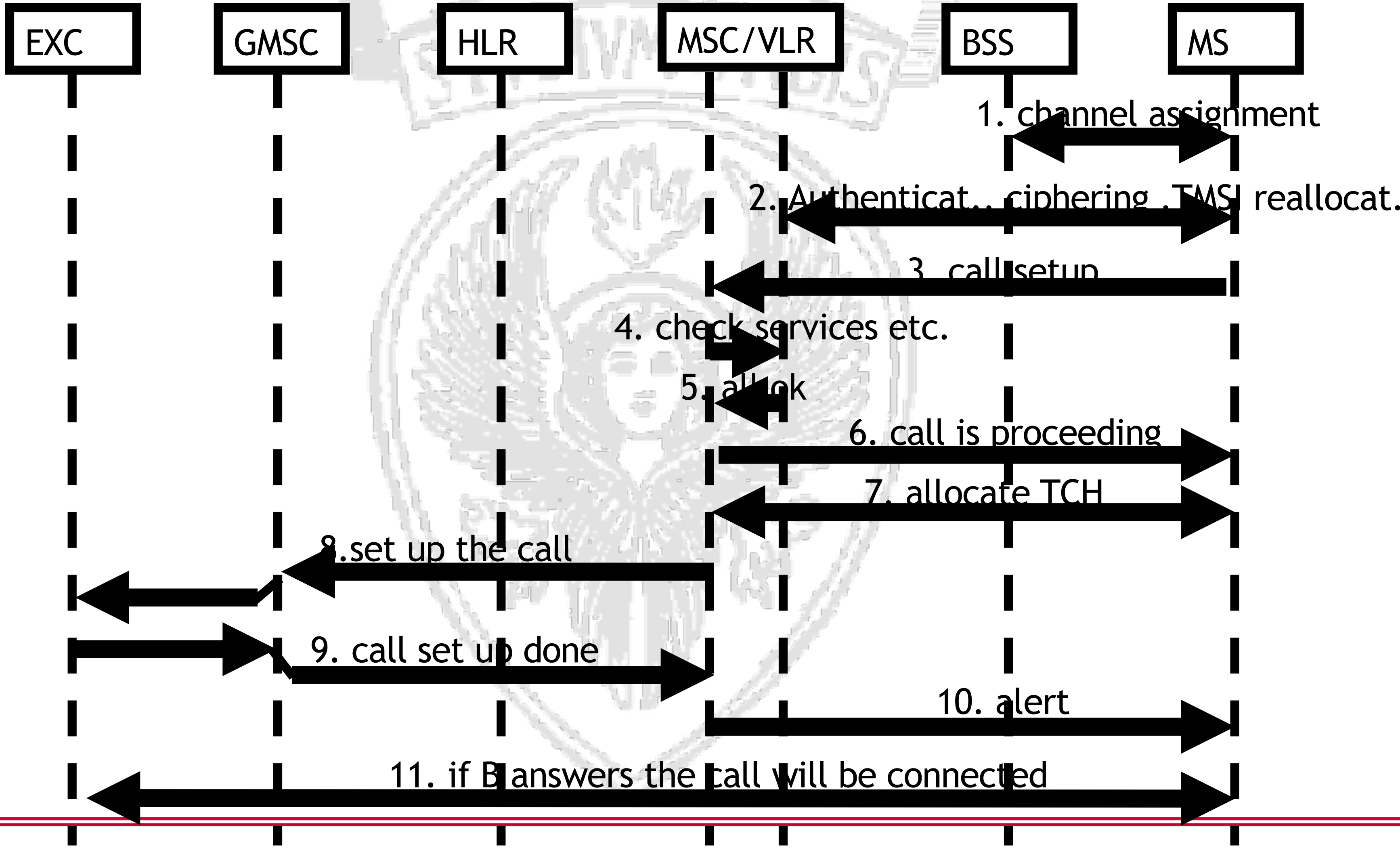
Summary of the Call Set-up Steps (2)



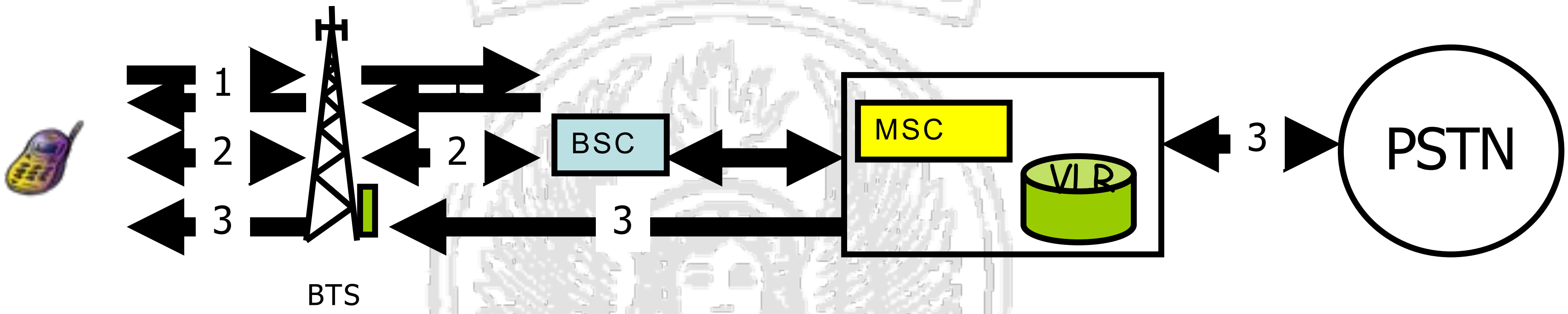
MS-originated call

- The called number is dialled by the MS
- The current MSC analyses the caller data and:
  - It either authorizes or deny the call
  - The call routing procedure is started
- If the called number is in the same GSM network, a "send routing info" procedure is started to obtain the MSRN
  - Same procedure as PSTN-originated calls
- If the called number is in another GSM network, the call is routed to the GMSC.

Summary of the Call Set-up Steps



Mobile-originated call (1)

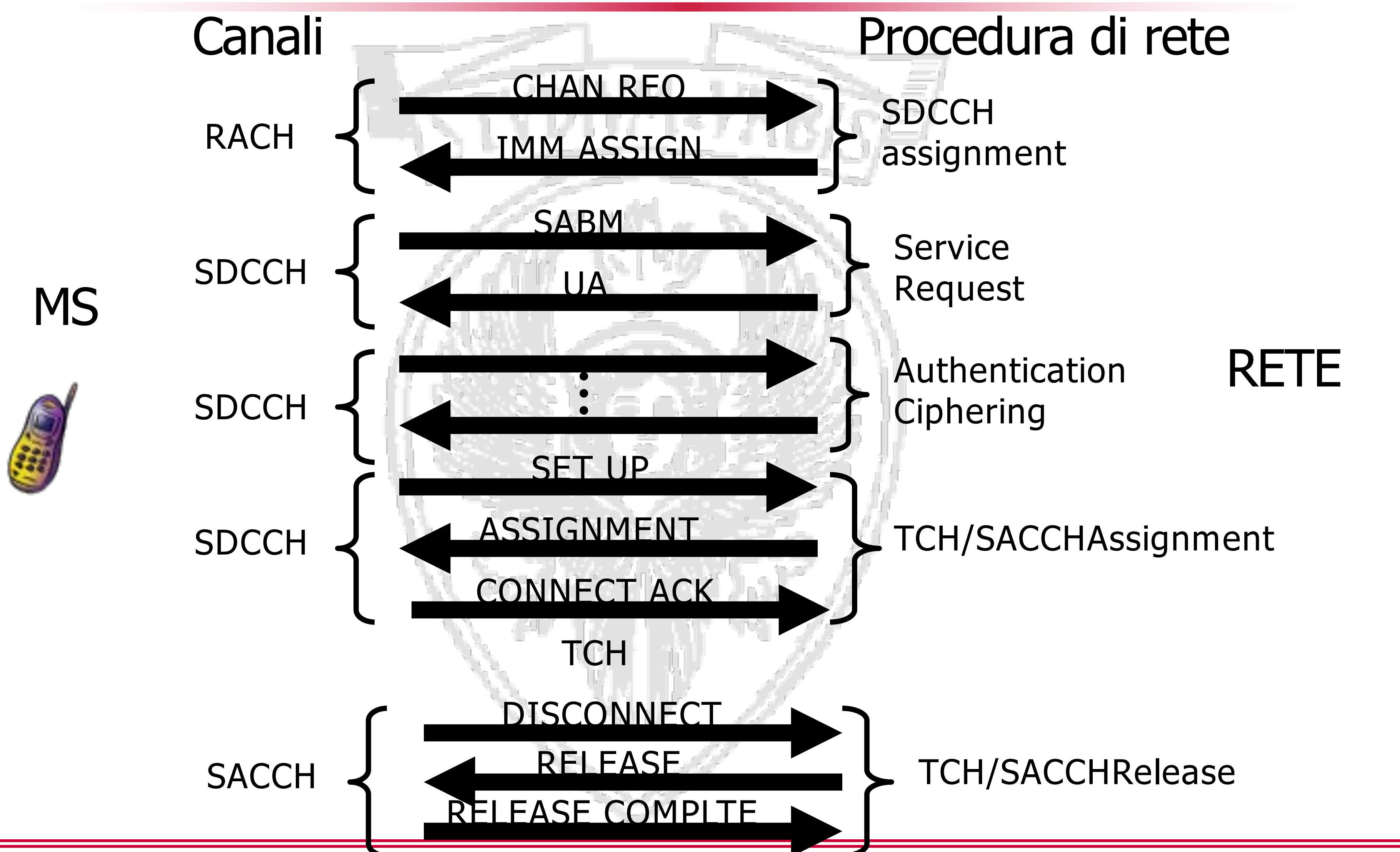


1- Access request, resource allocation for signaling

2 – Authentication and ciphering, caller id is transmitted, traffic channel is allocated

3 –Call routing

Mobile-originated calls (2)



Handover Procedure

Handover e GSM

- The handover procedure is initiated by the network, based on measurements provided by the MS
- When the MS connects to a cell, the BSC sends to it a list of "alternative channels" (the BCCH of 6 adjacent cells) whose signal strength should be monitored by the MS;
- The results of such measurements is transmitted by the MS to the BSC using the SACCH channel every 480 msec
- An handover may be started by the BSC based on measurements performed by both the MS and the BTS

Handover parameters

- The procedure requires
  - A set of rules to determine whether an handover is necessary
  - Dedicated procedures to commute the communication from the original radio channel to the new channel
- It should be transparent to the user

Handover parameters - MS

- Signal strength on the BCCH carrier of adjacent cells (RXLEVNCELLn)
- Signal strength on the active TCH channel (RXLEV)
- Quality of the active TCH channel (RXQUAL)

Handover parameters - BTS

- Signal strength from the MS on the traffic channel (RXLEV)
- Quality of the traffic channel from the MS (RXQUAL)
- Distance of the MS (Timing Advance)

Reasons for handovers

- Low quality transmissions (RXLEV and/or RXQUAL below threshold)
- The distance between the MS and the BTS is below a given threshold (timing advance)
- Motivated by traffic (high load on the cell)
- Control and maintenance

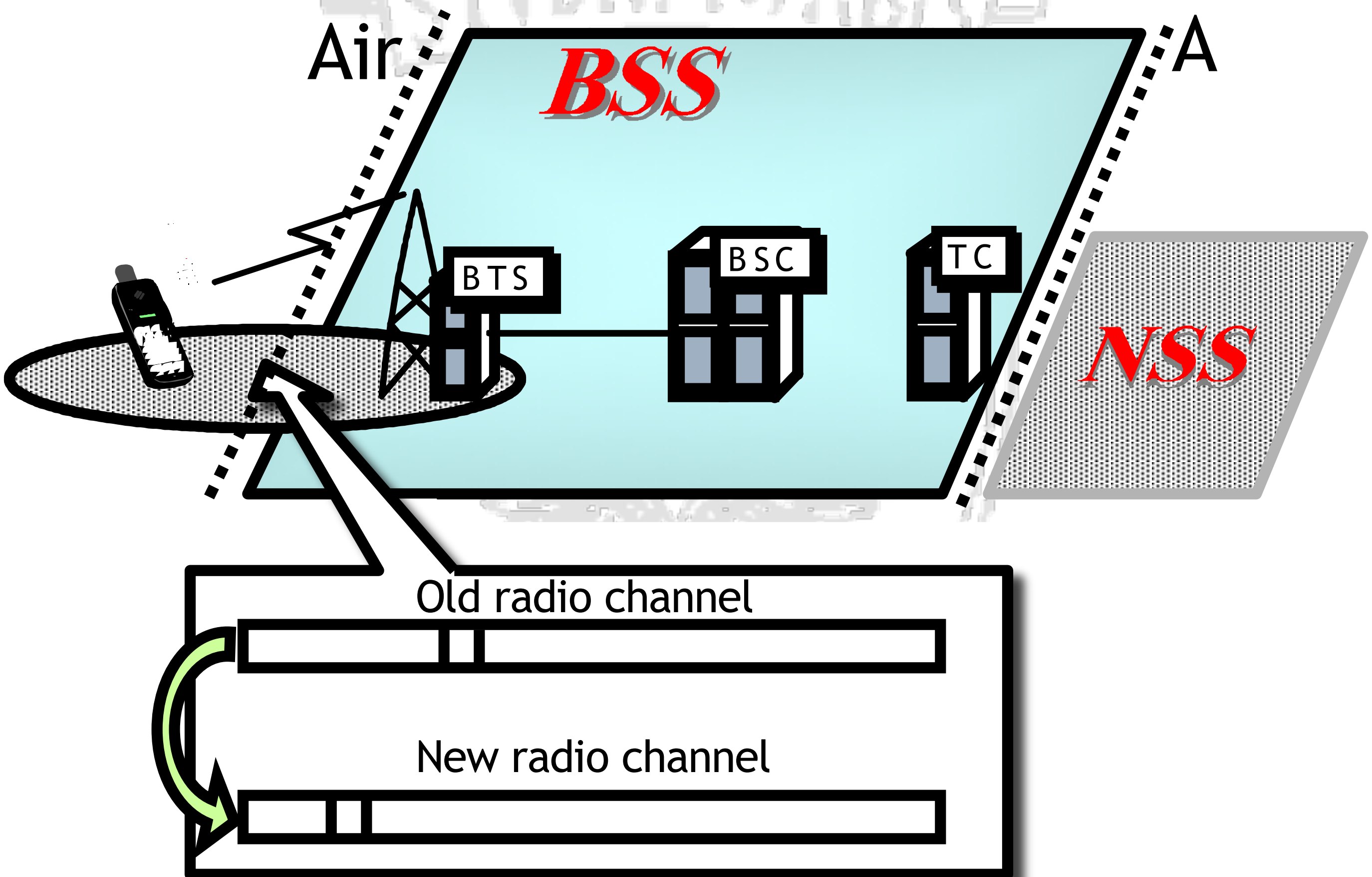
Types of Handovers

4 types of Handovers

- Intra Cell - Intra BSC
- Inter Cell - Intra BSC
- Inter Cell - Inter BSC
- Inter MSC

Handovers must be performed quickly! (<=100 ms)

Intra Cell – Intra BSC Handover



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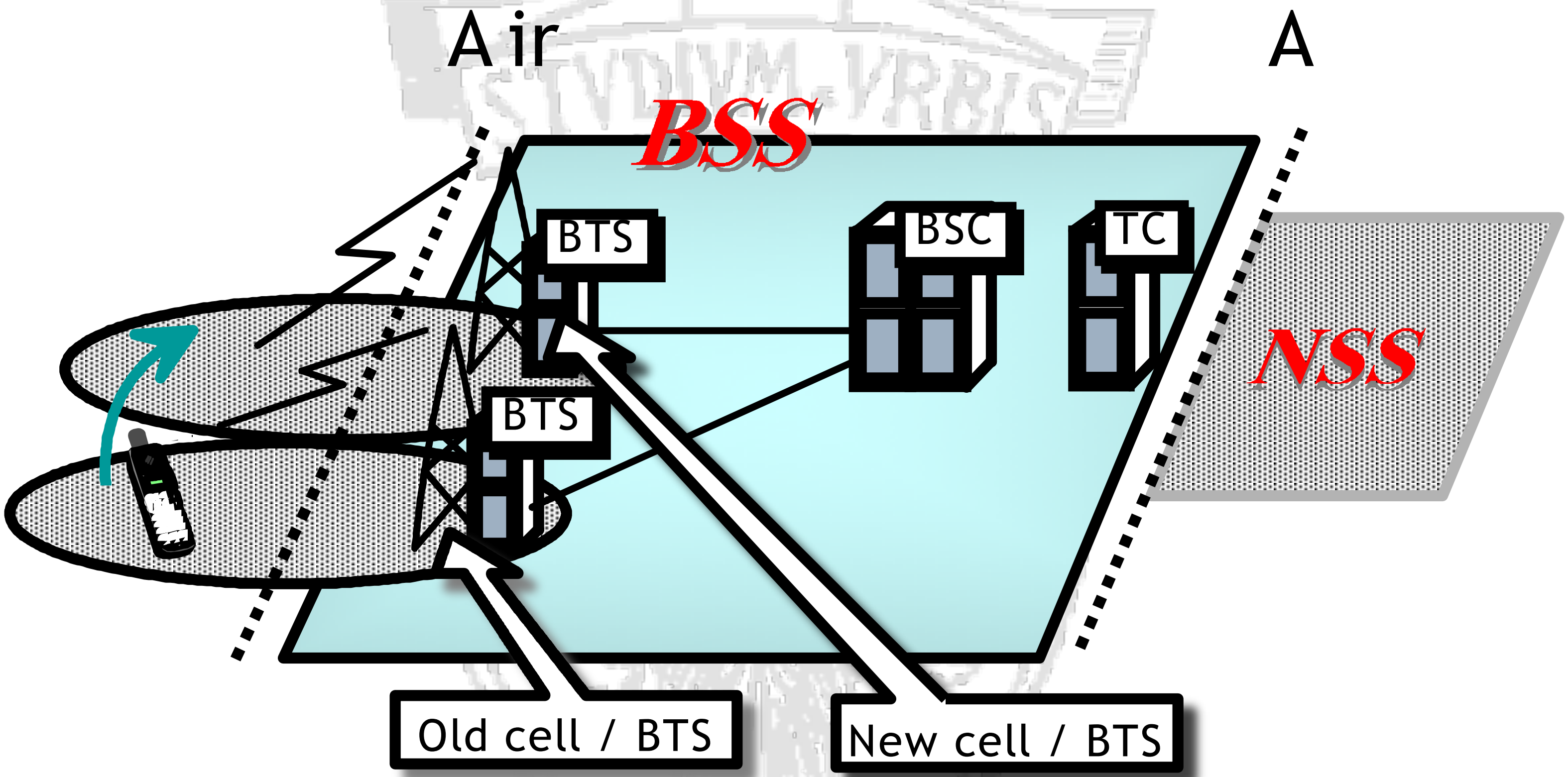
Intra Cell – Intra BSC Handover

- Simpler handover, decided by the BSC only
- A new traffic channel is allocated, usually the frequency within the BTS is modified as well
- Triggered by:
  - Low-quality TCH, high received signal strength
  - No adjacent BTS can provide better quality

Inter Cell – Intra BSC Handover



The MS moves to a new cell under the same BSC

Inter Cell-
Intra BSC Handover

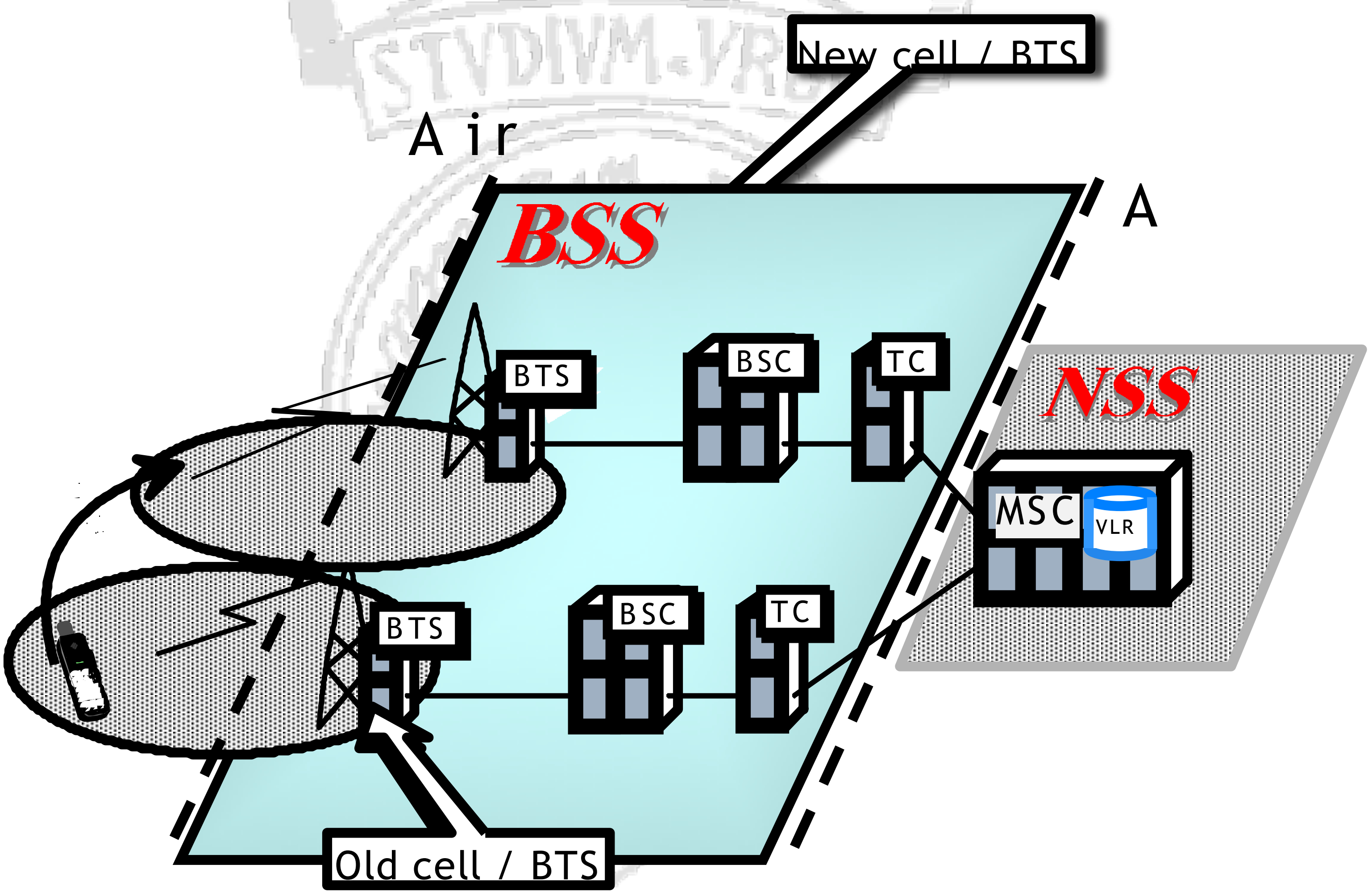
The handover procedure is fully controlled by the BSC

- The BSC identifies the best BTS and the best TCH for the MS, based on MS and BTS measurements
- The BSC connects to the new BTS and requires the allocation of a new TCH
- The BSC signals to the MS (using the logical channel FACCH) to use the new TCH. The old radio carrier is released.
- The MS starts sending traffic on the new TCH
- The old connection is released
- The BSC notifies the handover to the MSC/VLR

Additional Steps

- After the handover the MS must acquire information about the new adjacent cells. It uses the Slow Associated Control CHannel (SACCH)
- If the LA is changed by the handover, a Location Procedure must be triggered by the MS

Inter Cell – Inter BSC Handover

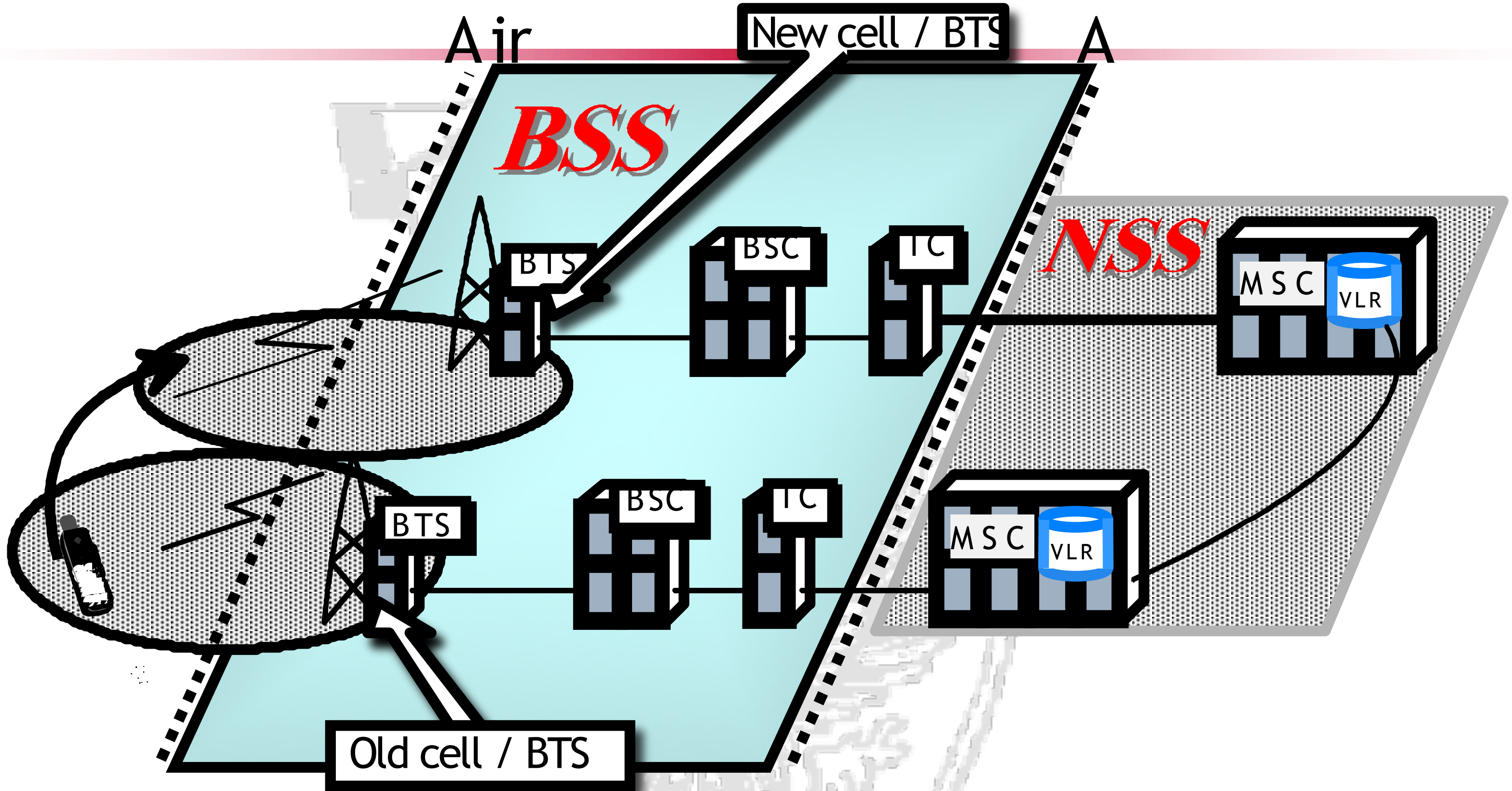


Inter Cell- Inter BSC Handover

The handover procedure is initiated by the BSC

- The BSC identifies the best BTS and the best TCH for the MS
- The current BSC sends a message to the MSC/VLR, as the new BTS is controlled by another BSC
- The MSC creates a connection to the new BSC
- The new BSC reserves a radio channel for the MS. The old carrier is released
- The new BSC sends a command to the MS, which should now use the new radio channel (TCH)
- The MS starts sending traffic on the new channel. The connection is routed by the MSC towards the new BSC
- The old connection is released

Inter MSC Handover



Handover is more complex because different MSC/VLR are involvede

- The call is routed by the initial MSC to the final MSC

Inter MSC Handover (1)

The handover procedure is initiated by the BSC

- The current BSC decides an handover towards a BTS controlled by another MSC/VLR
- The current BSC sends an handover command to the initial MSC/VLR
- The initial MSC/VLR sends a request to the final MSC/VLR
- The final MSC/VLR allocates an HandOver Number (HON), which is transmitted to the initial MSC/VLR

Inter MSC Handover (2)

- The destination MSC/VLR starts a connection to the new BSC
- A traffic channel is reserved to the MS by the new BSC
- The initial MSC/VLR sends an handover command to the MS by using the FACCH channel of the old BSC and BTS
- The MS switches to the new channel and starts sending traffic over the new TCH
- The old connection is released

HandOver Number

- Same format as MSRN and MSISDN
- HON = CC + NDC + SN
  - CC = Country Code
  - NDC = National Destination Code
  - SN = Subscriber Number
- SN points to a database
  - in case of MSISDN located in the HLR
  - in case of HON and MSRN located in VLR
- HON contains enough information to allow the GMSC to route the call towards the destination MSC

MS is switched off

- When a MS is switched off, it sends to the network a ***IMSI detached*** message
- The MSC/VLR flags the user as detached
- Paging is no longer performed until the MS is switched on again