PART 5
GSM – Switching & Mobility

Lecture 5.1
Protocol architecture overview

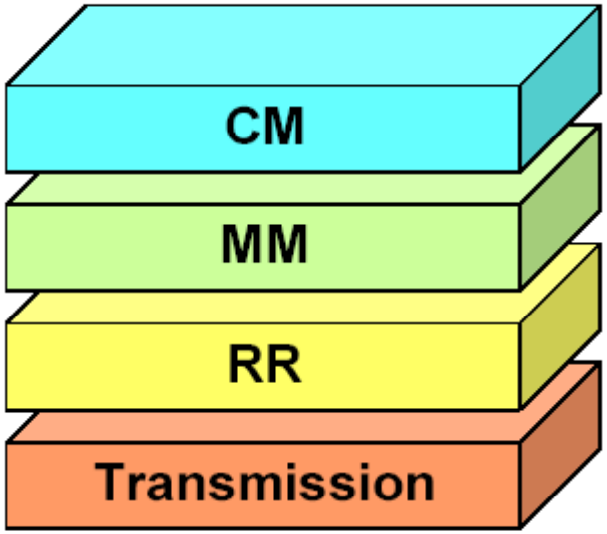
The GSM network layer

➔ **Divided in three sub-layers**

- ⇨ Radio Resource Management (RR)
  - →Provides a communication link between MS and MSC;
- ⇨ Mobility Management (MM)
  - →Manages DB for MS location
- ⇨ Communication Management (CM)
  - →Controls user connection

➔ **Underlying base:**

- ⇨ Transmission level



RR

- **Manages administration of frequencies and channels**
  - Mostly deals with air interface
    - Several RR functions considered in previous part
- **Guarantees stable link upon handover**
    - Surprise! handover is part of RR, not MM!
- **Function summary:**
  - Monitoring BCCH, PCH
  - RACH administration
  - Request/assignment of channels
  - MS power control & synchronization
  - Handover
- **Where is RR:**
  - MS, BTS, BSC, MSC

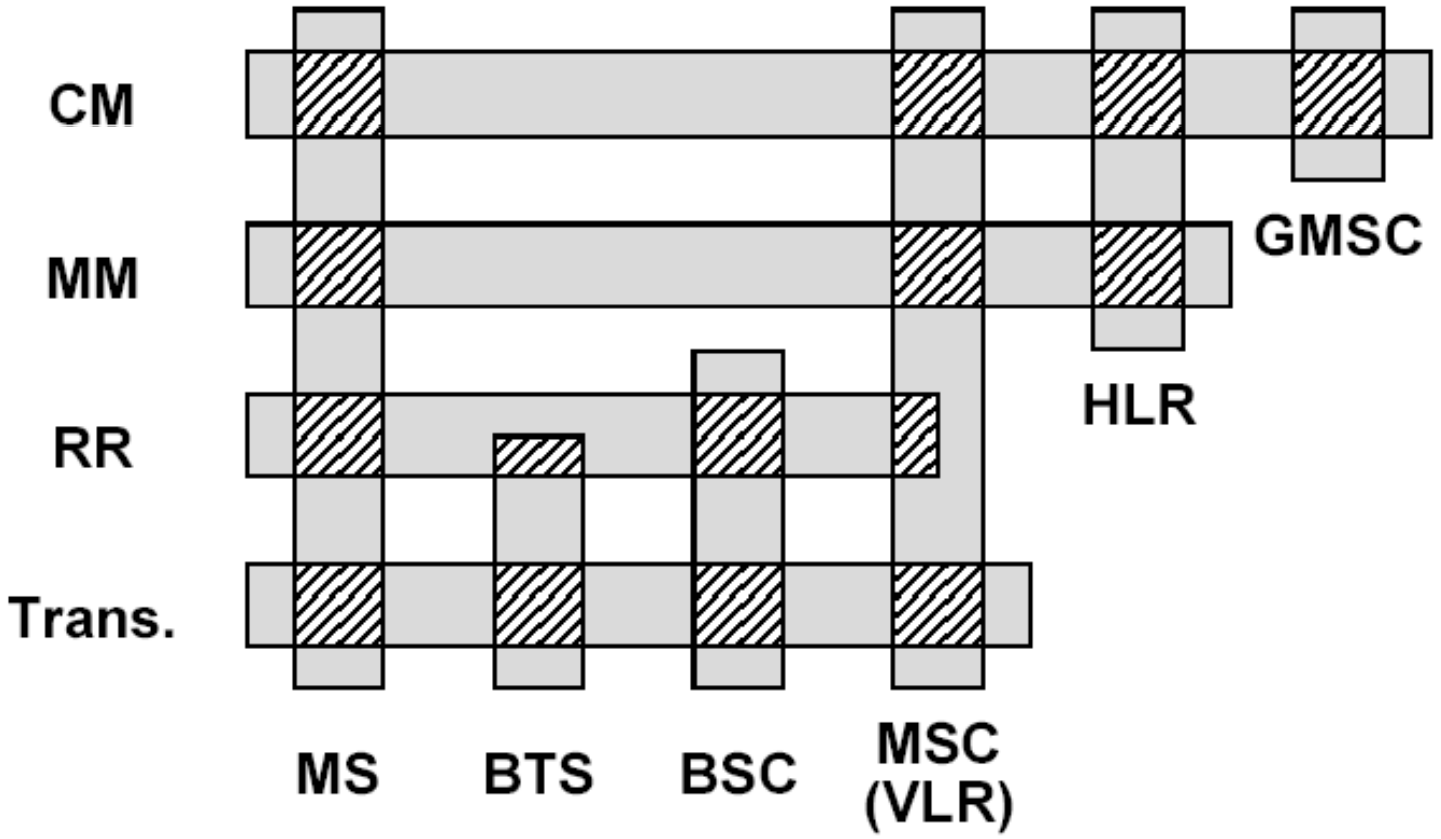
MM

- **Manages user location and tasks resulting from mobility**
- **Function summary:**
  - TMSI assignment
  - MS localization
  - Location updating
  - MS authentication
  - MS identification, attach/detach
- **Where is MM:**
  - MS, MSC

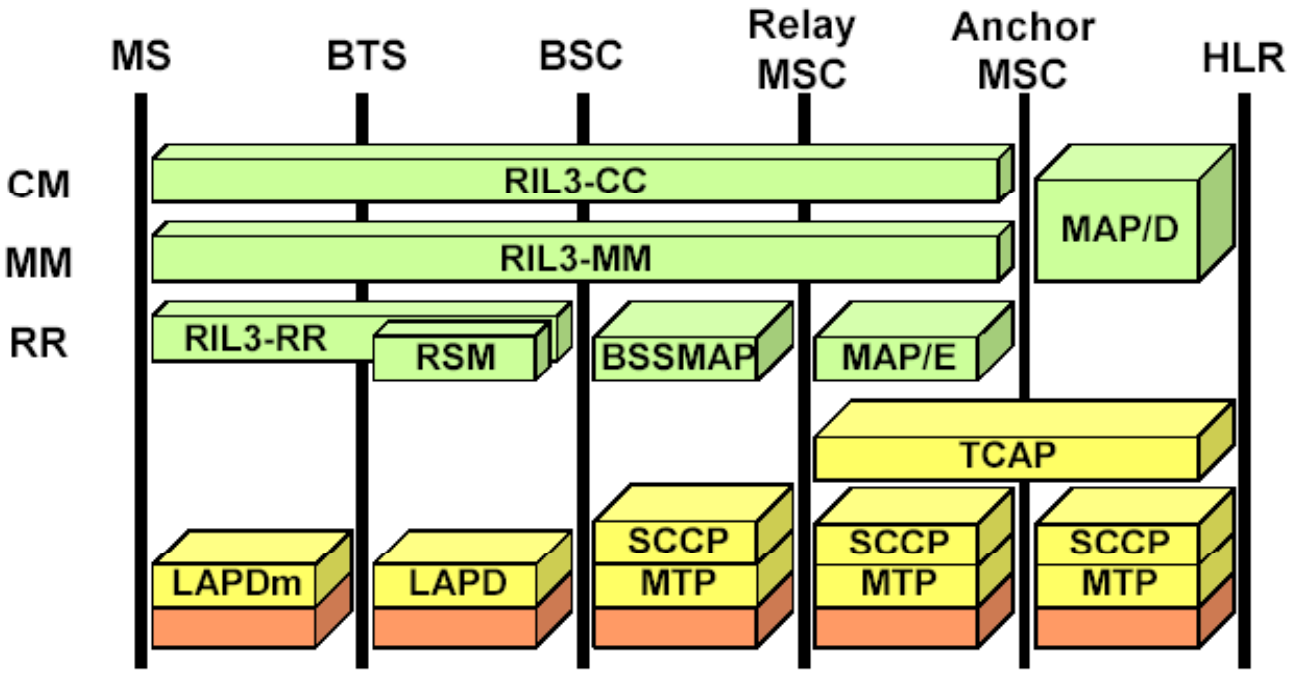
CM

- **Controls calls, supplementary services, and SMS**
- **Function summary:**
  - Call establishment (from MS, to MS)
  - Emergency call management
  - Call termination
  - DTMF signaling (Dual Tone MultiFrequency)
  - In-call modification
- **Where is CM:**
  - MS, MSC, GMSC

Protocol placement



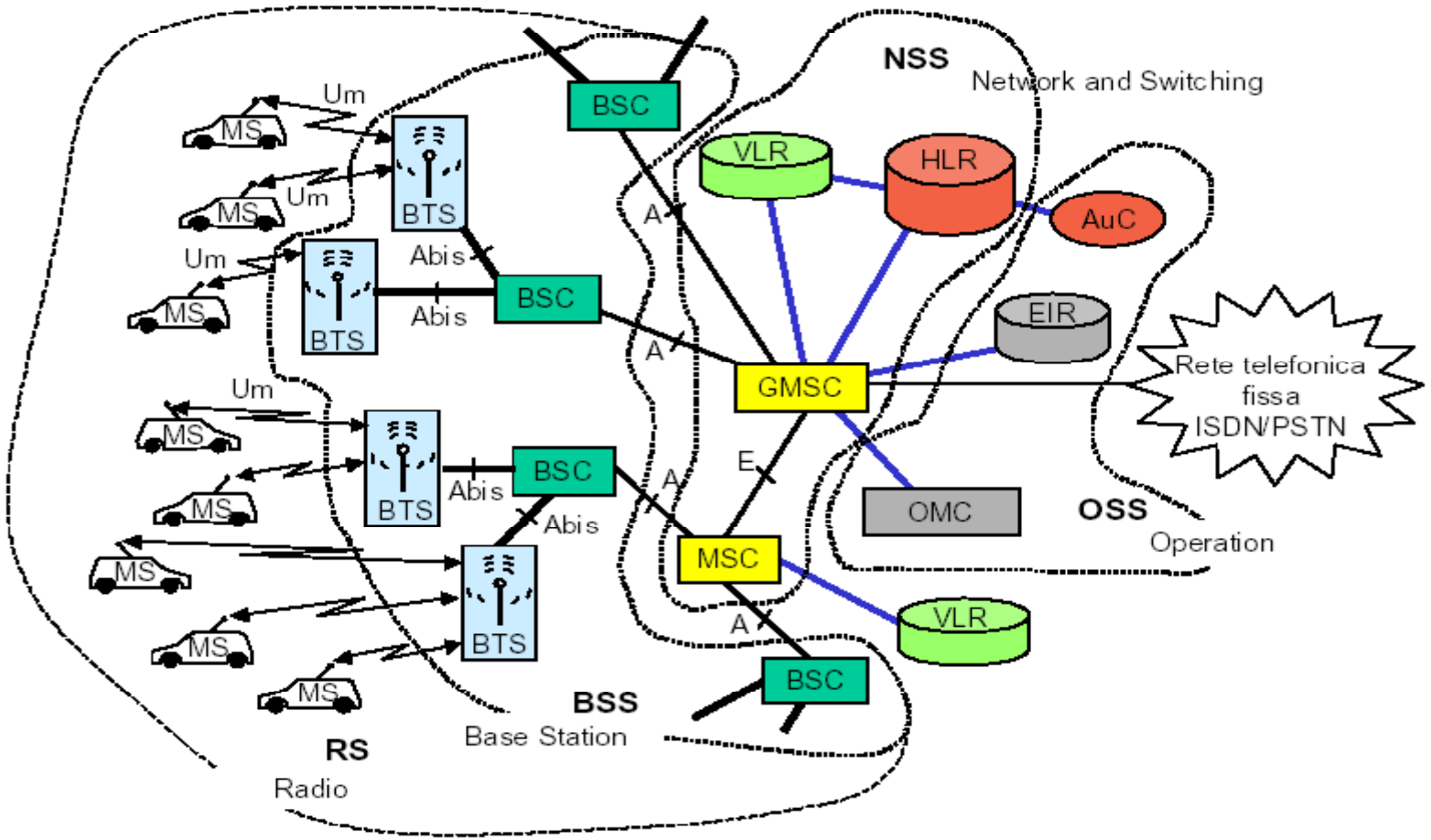
Protocol outline



RIL3: Radio Interface Layer 3
RSM: Radio Subsystem Management
BSSMAP: BSS Management Application Part
MAP: Mobile Application Part

TCAP: Transaction Capabilities Application Part
SCCP: Signaling Connection Control Part
MTP: Message Transfer Part
LAPD: Link access Protocol on D channel
LAPDm: Link access Protocol on Dm channel

Architettura del GSM



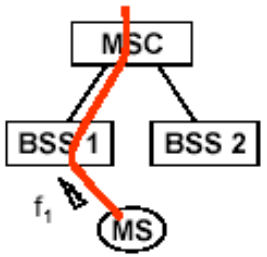
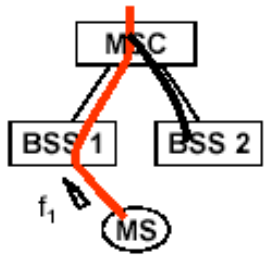
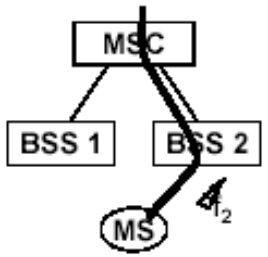
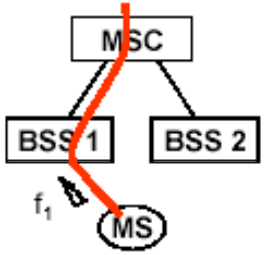
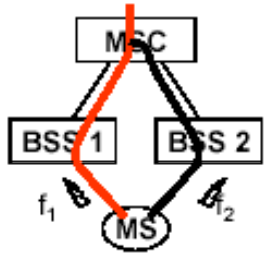
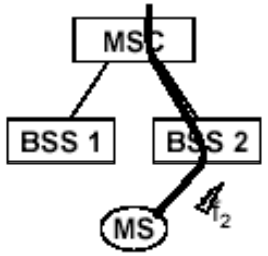
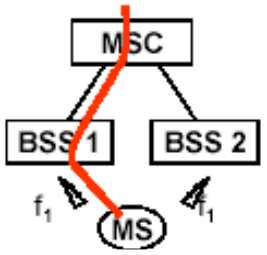
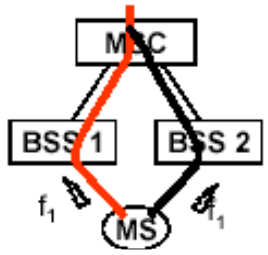
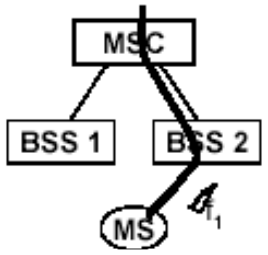
BSS	**Sistema stazione base**
BSC	**Controllore stazione base**
BTS	**Stazione base ricetrasmittente**
BS	**Stazione base**
MS	**Stazione mobile**
OSS	**Centro di gestione della rete**
OMC	**Centro operativo e di manutenzione**

NSS	**Sottosistema di rete**
MSC	**Centro di commutazione servizi mobili**
HLR	**Registro utenti locali**
VLR	**Registro utenti ospiti**
AuC	**Centro di autenticazione**
EIR	**Registro identità apparato**

handover

- **Procedure in which an MS releases a connection with a BTS, and establishes a connection with a new BTS, while ensuring that the ongoing call is maintained**
  - The MS remains in dedicated state (unlike cell reselection, where MS is in idle state)
- **Handoff: synonymous of handover**
- **Needs two mechanisms**
  - **Handover preparation:** detection of cell-border crossing
    - →Based on radio link quality measurements
  - **Handover execution:** setup of a new channel in a cell, and tear-down of a previous channel
- **Improved handover mechanisms:**
  - Seamless handover: when active call performance is not impaired
    - →Not possible in GSM: for about 100-200ms, communication is interrupted
  - Soft Handover: when two channels are simultaneously set-up (old and new)
    - →Not possible in GSM; possible in UMTS

Hard, Seamless, Soft handover

	before	during	after
Hard handover (GSM)			
Seamless (DECT)			
Soft handover (UMTS)			

Handover classification

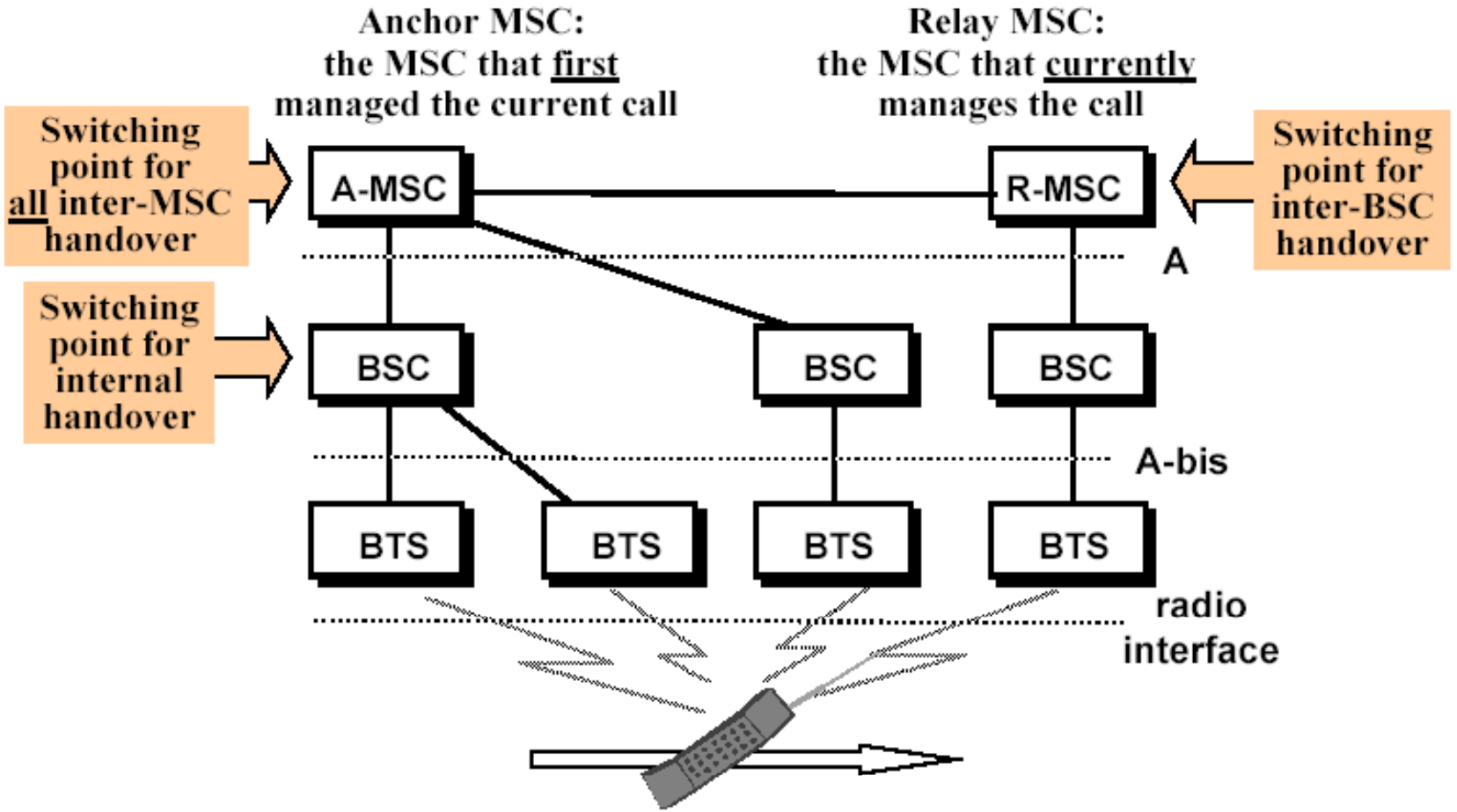
Classification by motivation

- **Rescue handover (mandatory handover)**
  - Driven by radio channel quality degradation
- **Confinement handover (network-directed handover)**
  - Target: minimize radio interference
  - Assign new channel when old channel results critical for total interference
- **Traffic handover (network-directed handover)**
  - Driven by traffic congestion conditions
  - Also called load-balancing

Classification by typology

- **Internal handover**
  - Intra-BTS
    - New radio channel in the same cell
    - Not termed as "handover" but as"subsequent assignment"
  - Inter-BTS (Intra-BSC)
    - Under control of same BSC
- **External handover**
  - Inter-BSC (Intra-MSC)
    - Change reference BSC; may imply a location area update
  - Inter-MSC
    - Most complex: need to change MSC

Types of handover



Handover taxonomy

- **BCHO: Base station Controlled Handover**
  - Handover detection: BS
  - Handover Execution: BS
- **MCHO: Mobile Controlled Handover**
  - Handover detection: MS
  - Handover Execution: MS
- **MAHO: Mobile Assisted Handover**
  - Handover detection: MS
  - Handover Execution: BS

- **GSM: somehow a BCHO with a flavor of MAHO**
  - Handover decision always taken by BSC
  - Based on measures taken at both BTS and MS
  - New channel selection decision taken at BSC or R-MSC or A-MSC (depending on handover type) based on traffic consideration

Handover preparation

➔ Measurements performed at BTS

- ⇨ Up-link signal level received from MS lower than threshold
  - →RXLEV_UL < L_RXLEV_UL_H
- ⇨ Up-link signal quality (BER) received from MS
  - →RXQUAL_UL < L_RXQUAL_UL_H
- ⇨ Distance between MS and BTS
  - →adaptive timing advance parameter > MAX_MS_RANGE
- ⇨ Interference level in unallocated time slots.

➔ Measurements performed at MS.

- ⇨ Down-link signal level received from serving cell
  - →RXLEV_DL < L_RXLEV_DL_H
- ⇨ Down-link signal quality (BER) received from serving cell
  - →RXQUAL_DL < L_RXQUAL_DL_H
- ⇨ Down-link signal level received from *n*-th neighbor cell
  - →RXLEV_NCELL(n) > RXLEV_MIN(n)

RX signal level	From (dBm)	To (dBm)
RXLEV_0	-	-110
RXLEV_1	-110	-109
RXLEV_2	-109	-108
RXLEV_3	-108	-107
…	…	…
…	…	…
RXLEV_62	-49	-48
RXLEV_63	-48	-

Bit error Ratio	From (%)	To (%)
RXQUAL_0	-	0.2
RXQUAL_1	0.2	0.4
RXQUAL_2	0.4	0.8
RXQUAL_3	0.8	1.6
RXQUAL_4	1.6	3.2
RXQUAL_5	3.2	6.4
RXQUAL_6	6.4	12.8
RXQUAL_7	12.8	-

A note on MS distance

➔ **Distance can be measured based on TA**

➔ **TA = advance bits**

⇨ Ideally, TA should be set as

$$TA[bits] \cdot t_{bit} = \frac{2d}{c} \quad \Rightarrow \quad d = \frac{TA}{2} \cdot c \cdot t_{bit}$$

⇨ Hence, the TA resolution, in mt, is:

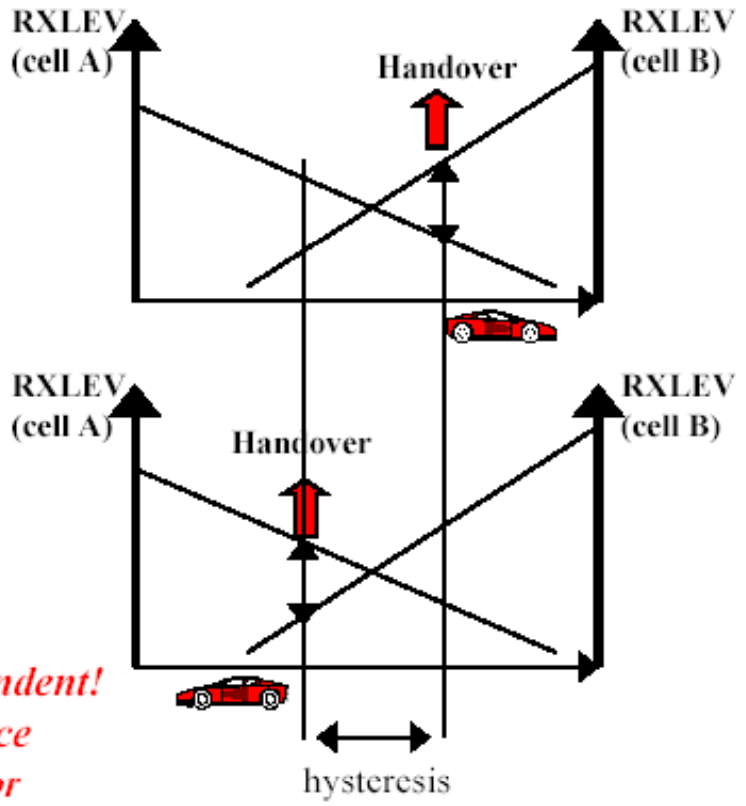
$$d(TA) = TA\frac{c \cdot t_{bit}}{2} = TA\frac{300000[mt/ms] \cdot \frac{1}{270.833}[ms]}{2} \approx TA \cdot 554mt$$

⇨ INSUFFICIENT for microcells!

⇨ Sufficient only to understand we are going out of the cell

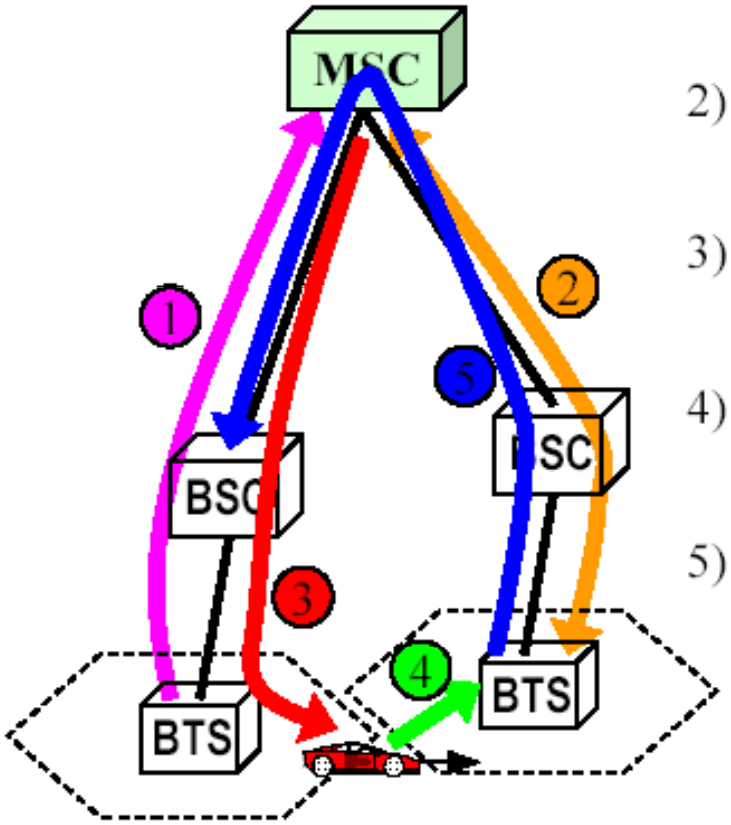
Handover preparation – additional metrics

- **Transmission power**
  - Maximum MS transmission power
  - Maximum serving BTS transmission power
  - Maximum neighboring BTSs transmission power
- **congestion status**
  - of serving BTS
  - of neighboring BTSs
    - → provided they can support the MS.
- **Handover Margin**
  - To avoid ping-pong handover effect
  - 5-10 dB in normal operation; up to 30dB in urban operation (to fight shadowing)



HANDOVER ALGORITHM: operator-dependent!
GSM standard SUGGESTS a simple reference algorithm, but implementation left to operator

handover procedure skeleton



1) Handover request goes up to switching point

2) Switching point prepares new path on fixed net

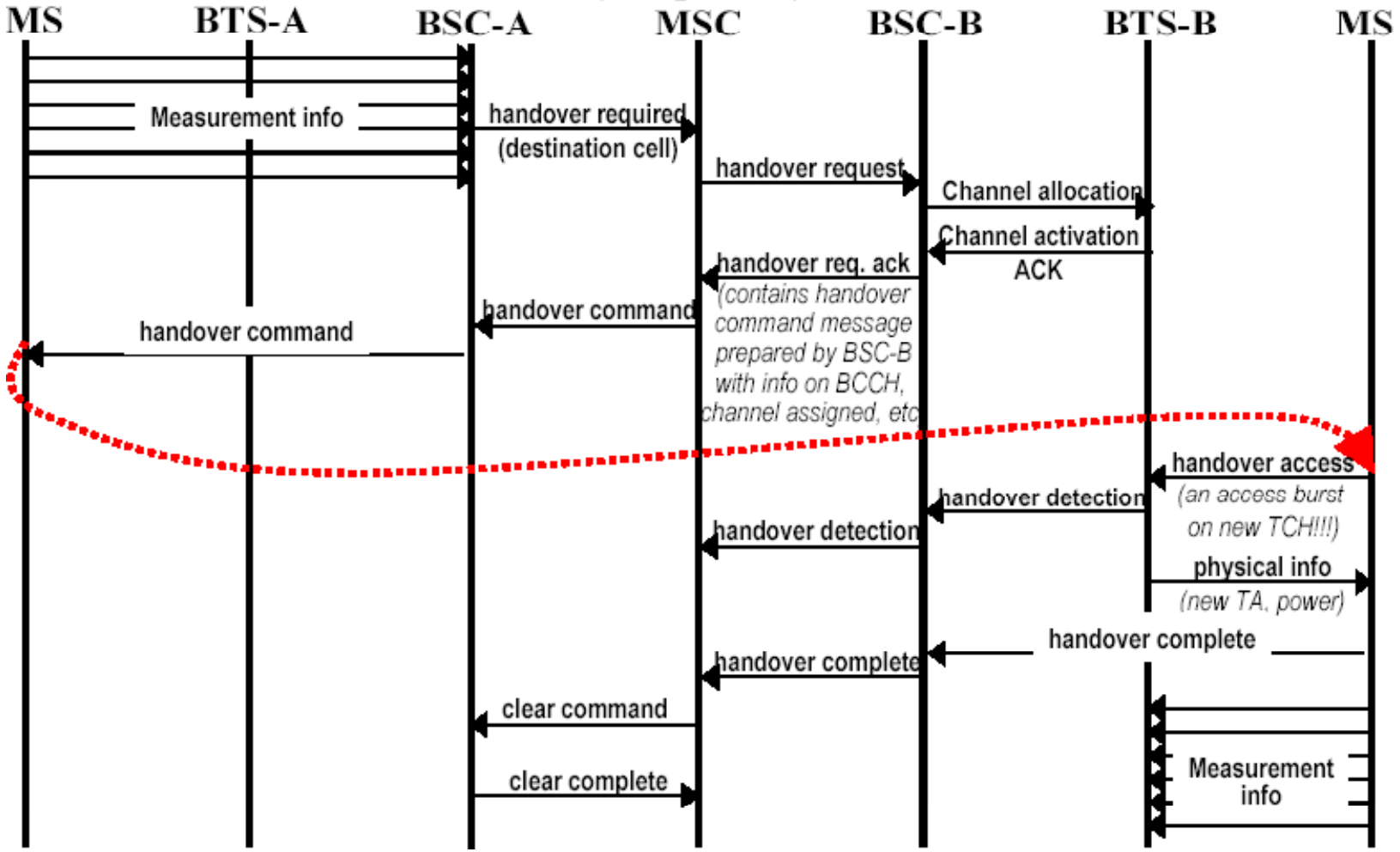
3) Switching point sends HO command to MS

4) MS accesses new channel

5) Old channel/path torn down

Signaling for intra-MSC handover

(simplified)



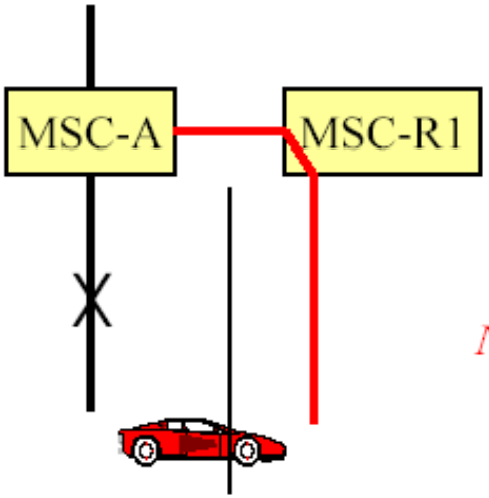
Inter-MSC handover

➔ **More complex, as an ISDN circuit must be set between MSCs**

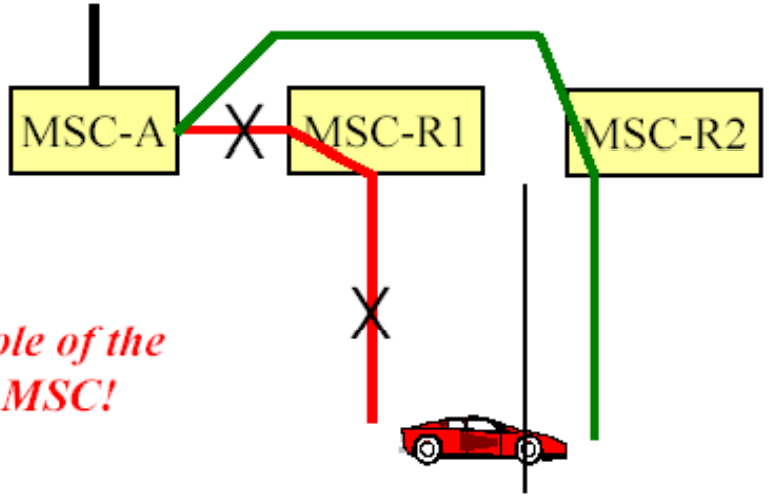
⇨ We'll not enter into details (just the basic ideas)

➔ **Two cases**

First MSC change (basic handover)



Second MSC change (subsequent handover)

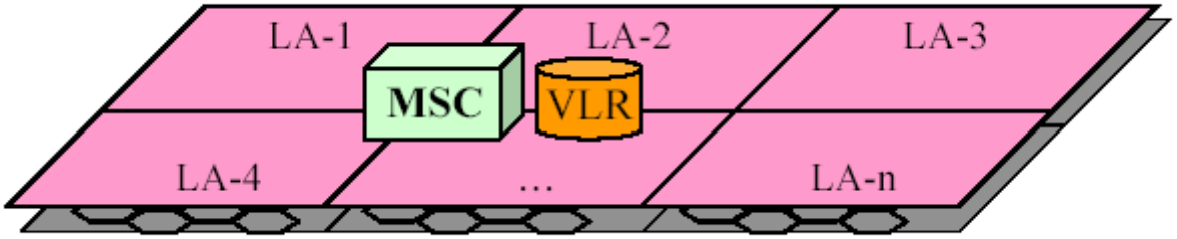


Note the role of the Anchor MSC!

GSM – Switching & Mobility

Lecture 5.3
location registration/update
Authentication & Ciphering

Location Area
vs
MSC service area



Registration vs update

➔ **Very similar procedures, with goals:**

- ⇨ Determine where the user is
- ⇨ Authenticate user

➔ **Differences:**

- ⇨ Location Registration
  - →User first access to PLMN
    - » Needs to send IMSI and receive TMSI
- ⇨ Location Update
  - →Subsequent accesses to PLMN (either in old or new MSC/VLS)
    - » Also after MS shut-down!
    - » TMSI-based identification

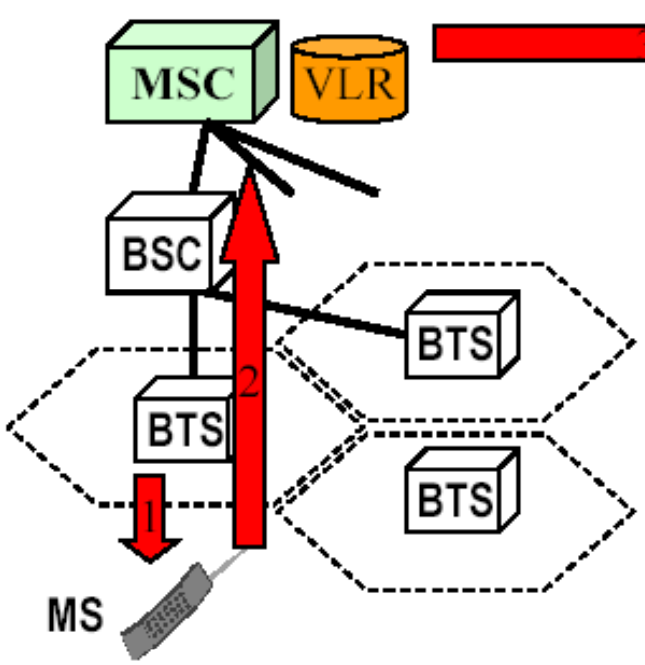
➔ **Registered user:**

- ⇨ The PLMN knows the LA where the user is (or is supposed to be)

Procedure start-up

- **MS switches on**
- **Detects BCCH carrier**
  - Tune and synchronize
- **Listens to BCCH**
- **Obtains Location Area Identifier**
  - LAI: [CC,MNC,LAC]
    - Country Code (CC): 3 digits
    - Mobile Network Code: 2 digits
    - Location Area Code: max 5 digits

LR/LU (very) basic idea

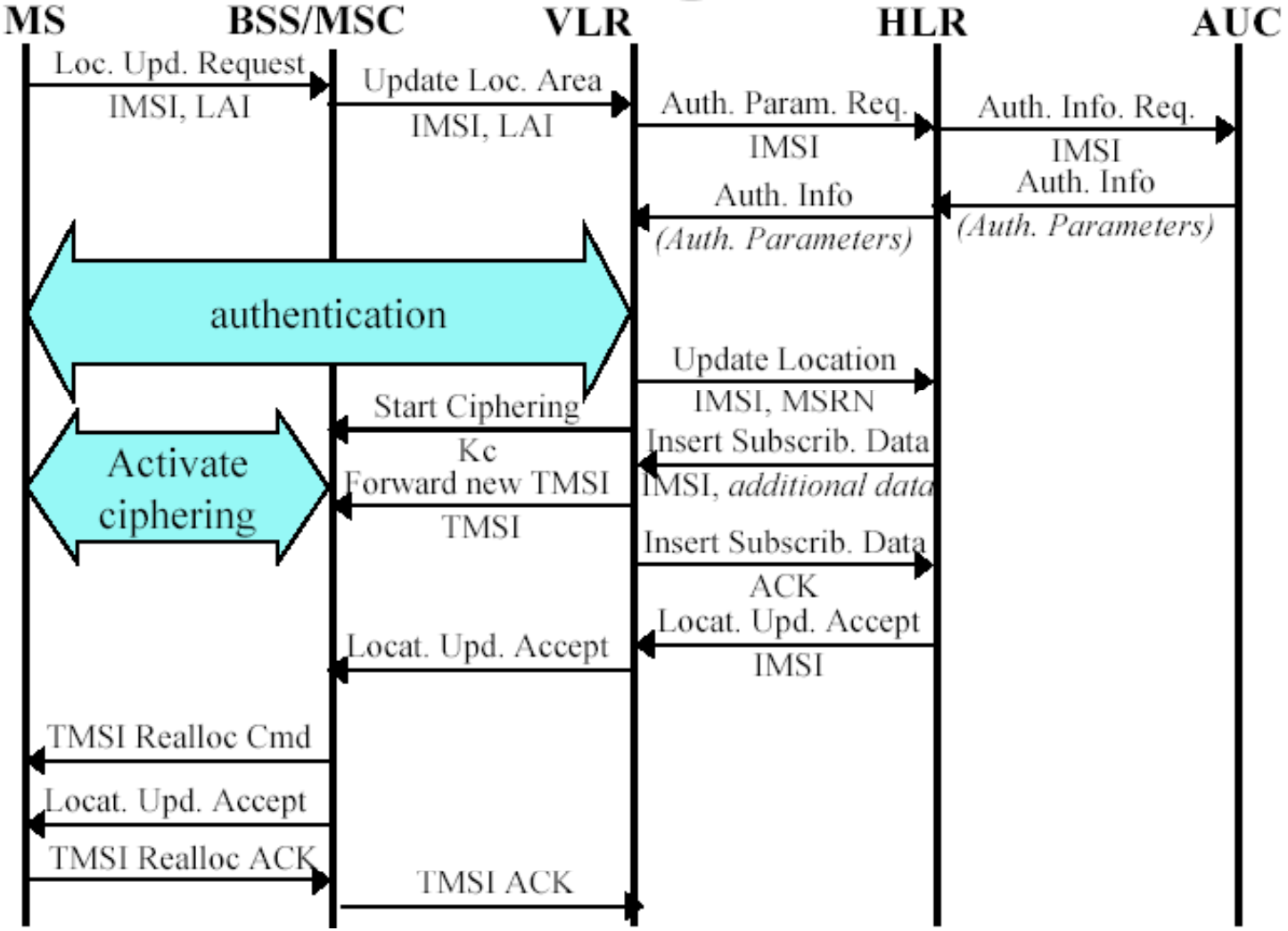


1) Obtain LAI from BCCH

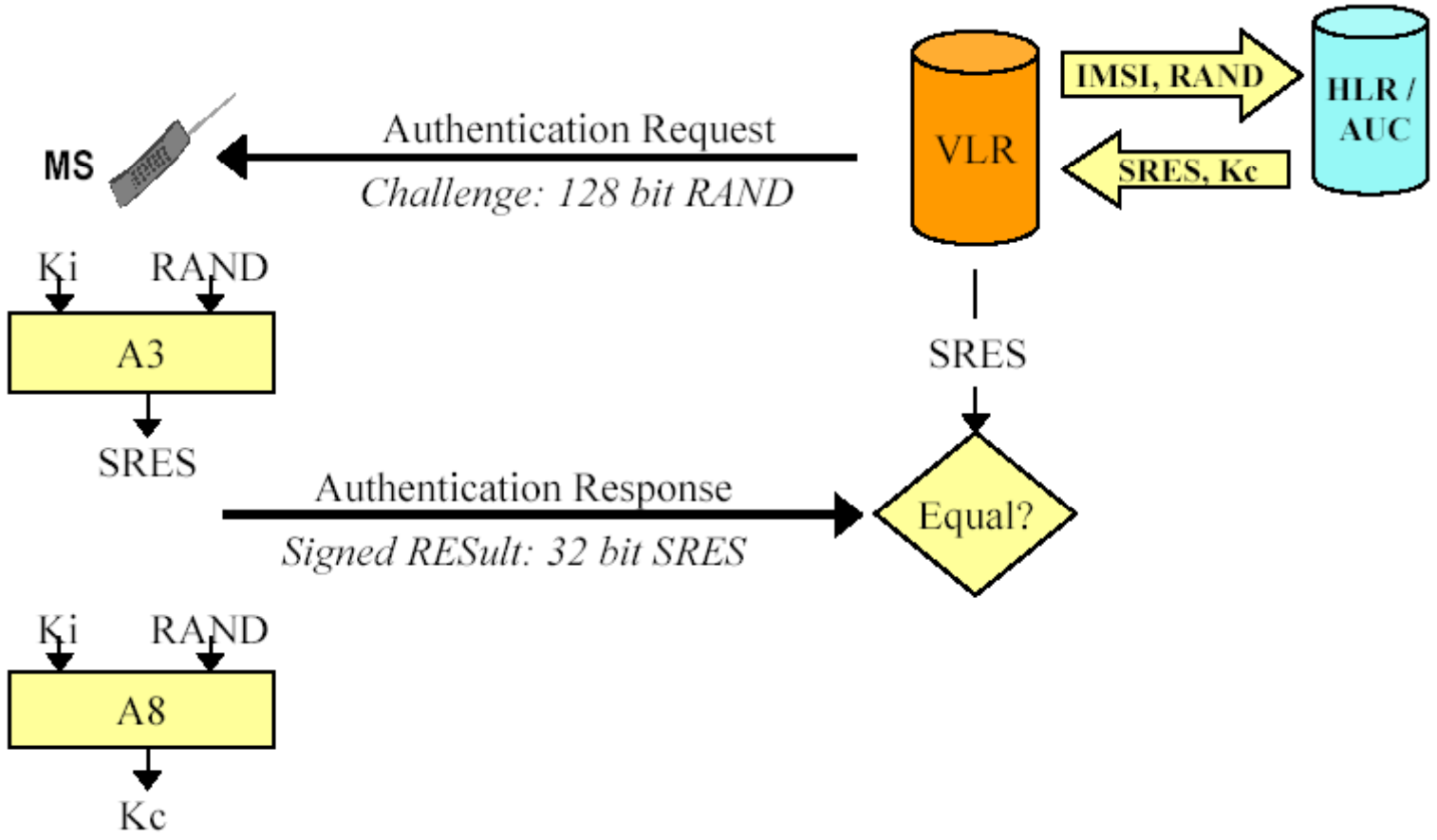
2) Register MS ID into local VLR

3) Update pointer at HLR

Location Registration



Authentication
(managed by VLR)

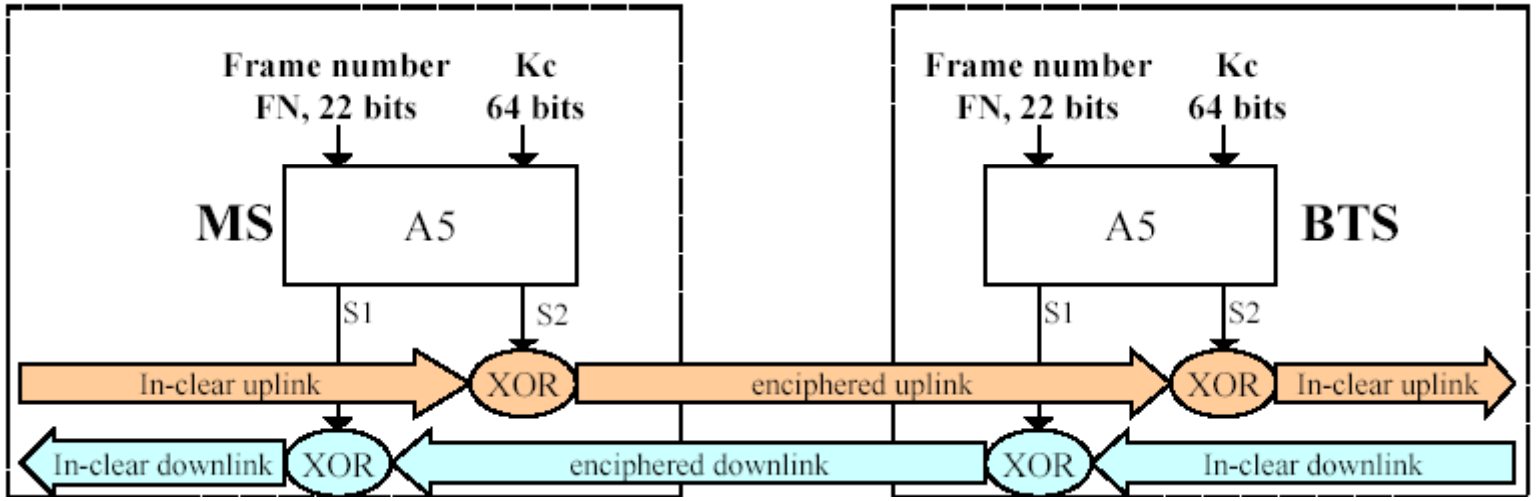


Authentication (details)

- **Side effect of authentication:**
  - Generate encryption key Kc via A8 algorithm
- **Secret A3, A8 algorithms (one-way hash functions)**
  - Stored into the SIM
    - Along with secret key Ki
  - Note that roaming operator DOES NOT need to know them!
    - Since A3,A8 run ONLY in the AUC at the home HLR
    - Ki is NEVER transmitted away from AUC or MS!
- **Generally implemented together**
  - [SRES,Kc] = A38[Ki,RAND]
- **To reduce signaling, real implementation slightly different:**
  - VLR sends IMSI
  - Receives back several tuples of (RAND, SRES, Kc) to be used for the considered MS also in subsequent accesses

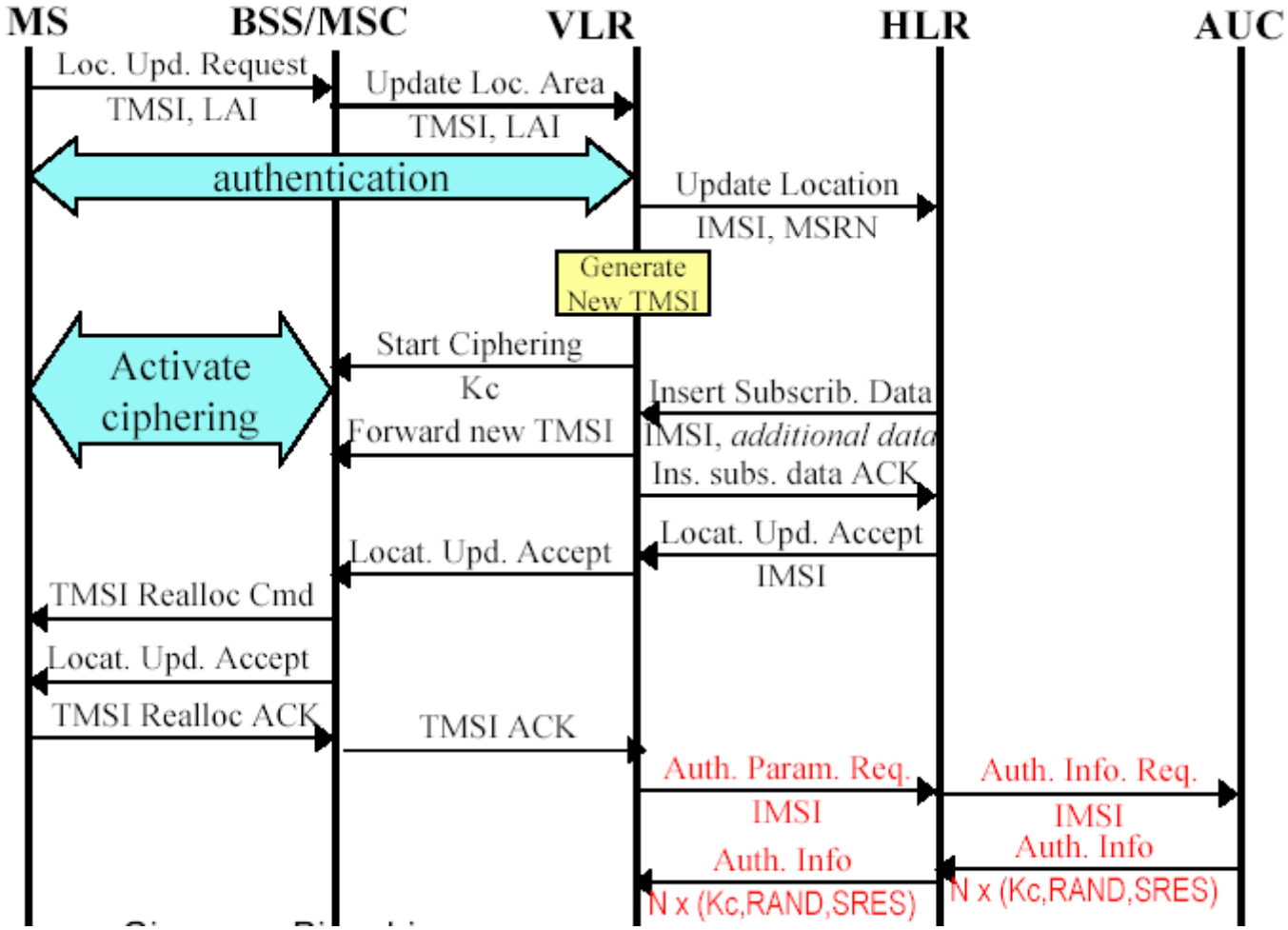
ciphering

- **A5 algorithm is known (to allow roaming)**
- **Generates two ciphering sequences**
  - one for uplink, one for downlink
  - Sequence periodic with period 26x51x2048=2,715,648
    - 2^{21}=2,097,152 < 2,715,648 < 2^{22}=4,194,304
- **114 bits per frame, depending on frame number**
- **XOR-ed with burst data field**

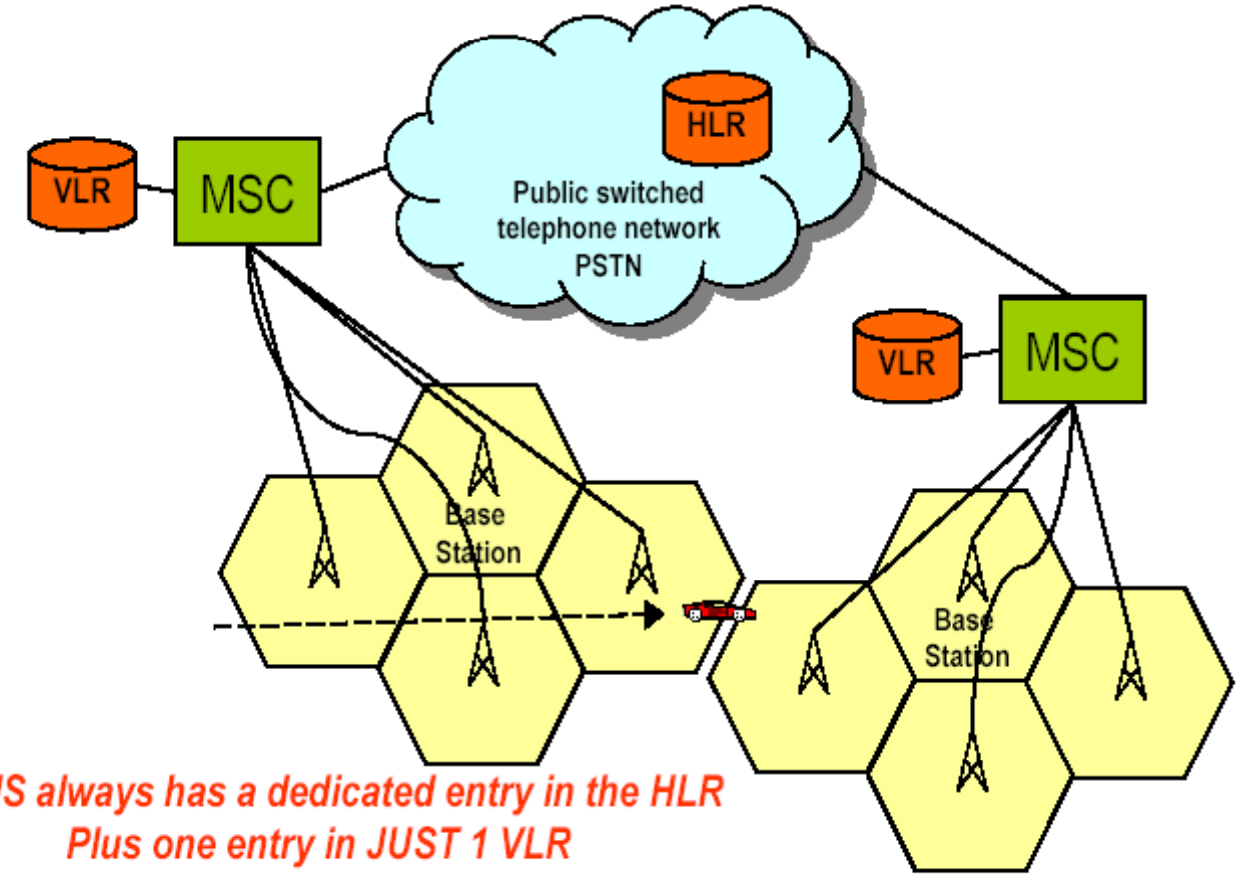


Location Update in same VLR

(same as location registration, but with TMSI)



Changing MSC/VLR



An MS always has a dedicated entry in the HLR
Plus one entry in JUST 1 VLR
(related to the MSC the user is connected to)

TMSI

➔TMSI = Temporary Mobile Subscriber Identity

- ⇨4 octets (32 bits)
- ⇨Renewed periodically; at every LU / IMSI_attach
  - →Via TMSI_Reallocation_Command/TMSI_Reallocation_Complete
  - →RATIONALE: renew TMSI when transmitted in clear! (TMSI reallocation occurs in ciphering mode)

Operator may set a 6min up to 24hrs periodicity for LU (value transmitted on BCCH)

IMSI_attach = a special LU in a same Location Area;

IMSI_attach follows an IMSI_detach (power-down of MS)

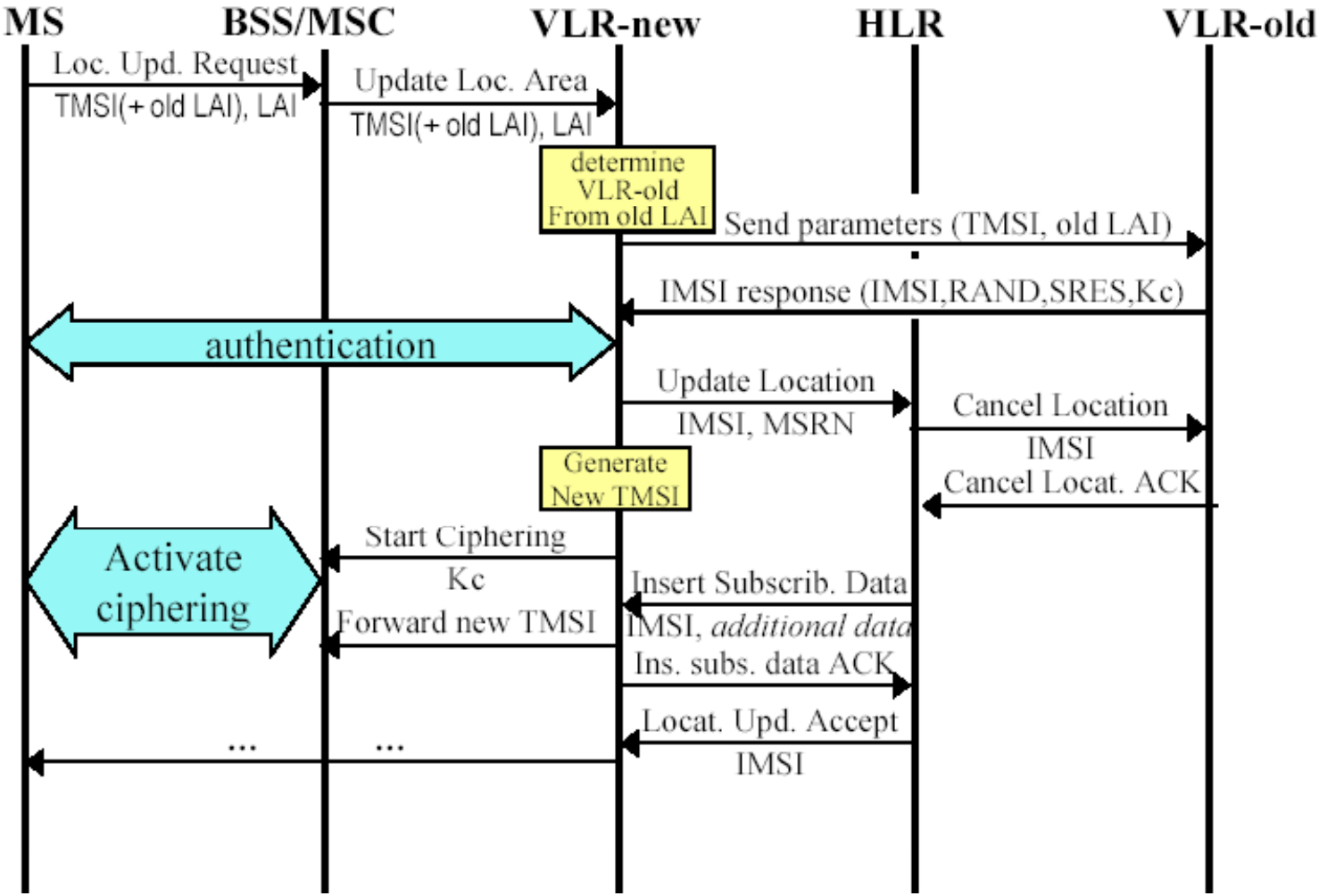
➔Meaningful only in a given VLR

- ⇨Specifically, only for a given Location Area!!
  - →Some author (Mouly-Pautet) uses the term
    - » TIC (Temporary Identity Code) = 4 bytes
    - » TMSI = TIC+LAI = unambiguous user identification

➔While entering a new Location Area:

- ⇨ user must identify itself with TMSI+LAI pair.

Location Update: different VLR

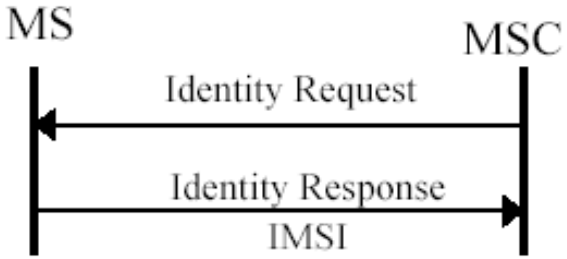


Special cases

1. **New VLR not capable of determining old VLR from old LAI**
2. **Old VLR does not recognize TMSI**

⇨ Identification procedure

→ IMSI transmitted in clear



PAGING:
- Normally based on TMSI
- But when no valid TMSI information available (e.g. after a DB restore after crash), based on IMSI

GSM – Switching & Mobility

Lecture 5.4
Call Management & routing