Cellular Mobile Networks - GSM
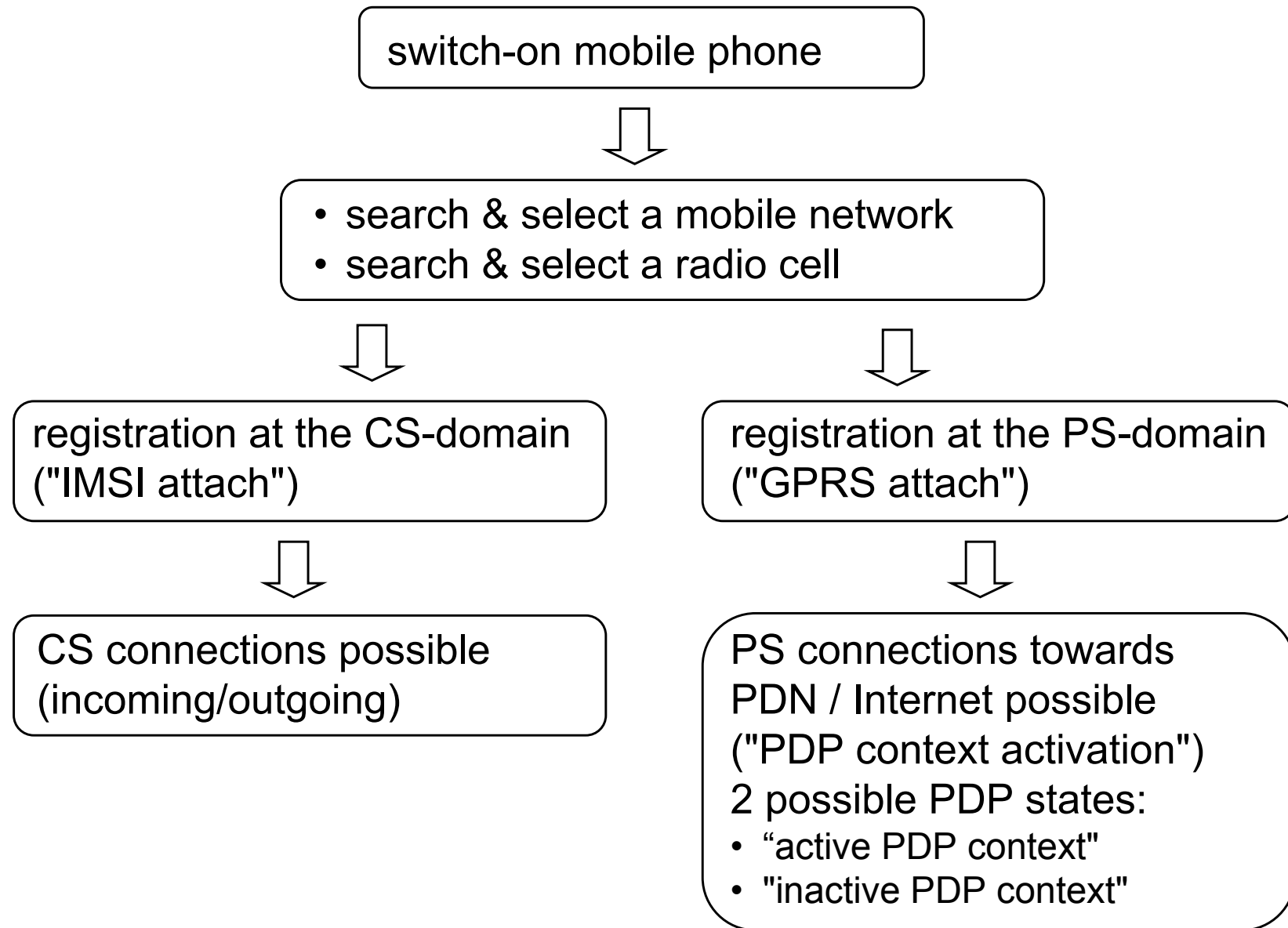# GSM Connection and Mobility Management

Contents - GSM - GSM Connection and Mobility Mgmt.
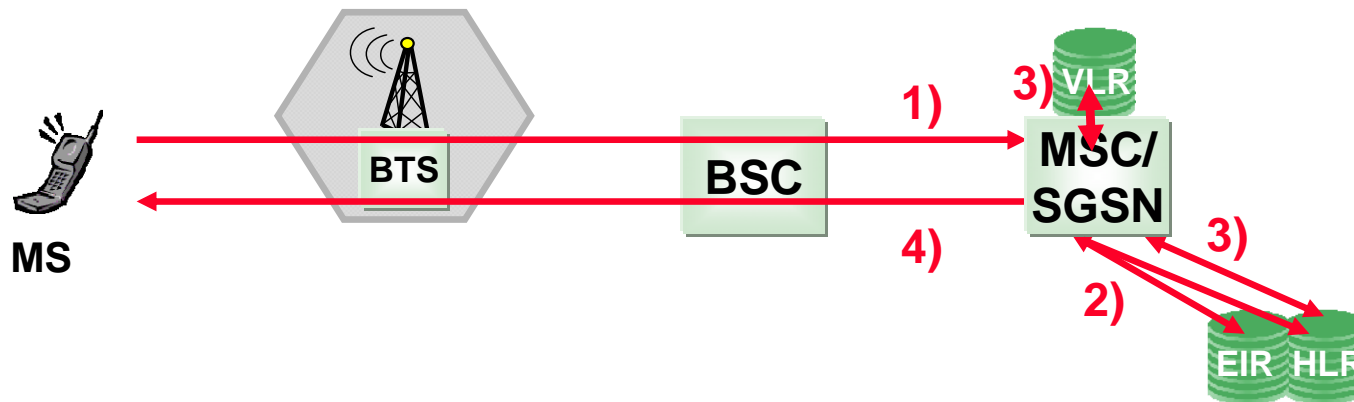
- GSM Connection Management and Routing
- GSM Mobility Management

GSM Connection Management

Steps before Connection Setup

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                    ┌─────────────────────────┐
                    │  switch-on mobile phone  │
                    └─────────────────────────┘
                                 ⇩
            ┌────────────────────────────────────────┐
            │  • search & select a mobile network     │
            │  • search & select a radio cell         │
            └────────────────────────────────────────┘
                 ⇩                         ⇩
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| registration at the CS-domain ("IMSI attach") | registration at the PS-domain ("GPRS attach") |

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                 ⇩                         ⇩
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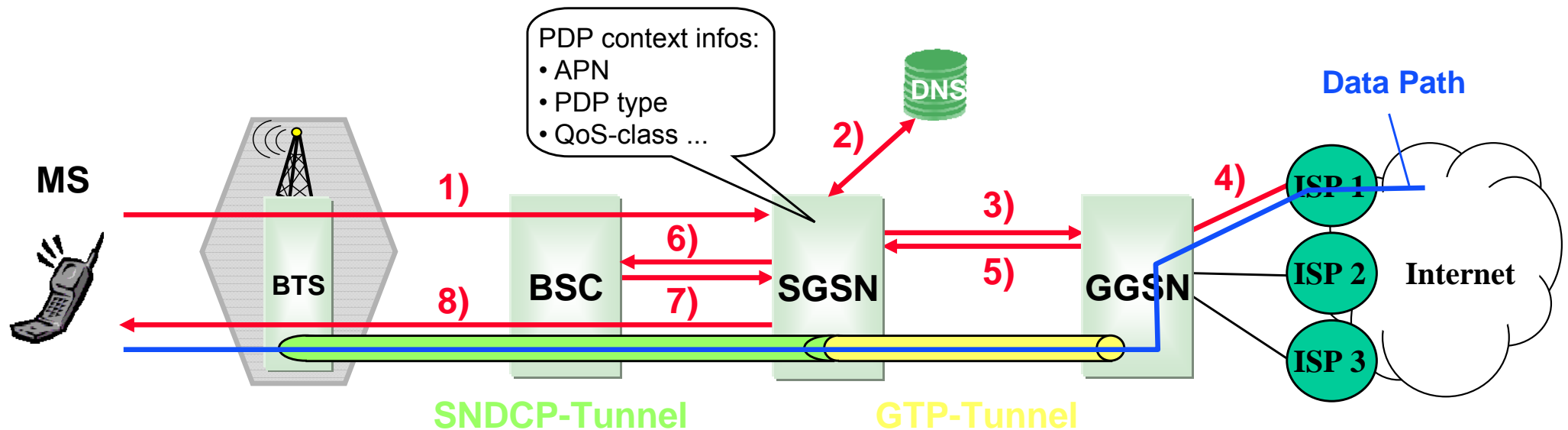| CS connections possible (incoming/outgoing) | PS connections towards PDN / Internet possible ("PDP context activation") 2 possible PDP states: • "active PDP context" • "inactive PDP context" |

Attachment to the CS- or PS-Domain (IMSI / GPRS Attach)

1) The MS sends an attach request to the MSC (or to the SGSN for GPRS)

2) Before the MSC (or the SGSN) performs the attach, it authenticates the subscriber (through a query to the HLR) and if necessary it checks the identity of the mobile phone (through a query to the EIR) and activates the encryption

3) The MSC (or the SGSN) registers the MS at the CS-domain (or PS-domain): the HLR is informed about the registration in the respective database (VLR or SGSN); in return the HLR sends subscriber specific informations (subscribed services, allowed PDP contexts) to the MSC (or the SGSN)

4) Finally the MS is provided with a temporary identity in the CS-domain (TMSI) or in the PS-domain (P-TMSI)

PS Connection Setup (PDP Context Activation)

PDP context infos:
- APN
- PDP type
- QoS-class ...

Data Path

MS · BTS · BSC · SGSN · DNS · GGSN · ISP 1 · ISP 2 · ISP 3 · Internet

1) 2) 3) 4) 5) 6) 7) 8)

SNDCP-Tunnel   **GTP-Tunnel**

Packet Data Protocol (PDP) Context:

The PDP context contains all informations, which are required for data transmission:
- the required quality of service (QoS-class)
- the Access Point Name (APN): e.g. the name of the ISP
- the PDP address type (e.g. IPv4) and if necessary the address of the MS, by which it can be reached from the PDN/Internet

More than one PDP context per subscriber are possible. Before the PS connection is established, it is checked, if the attributes of the requested PDP context match the attributes of the subscription of the user.

PS Connection Setup (PDP Context Activation)

1) The MS sends an PS connection setup request ("Activate PDP Context Request") with the PDP-type (e.g. IPv4 protocol) and the Access Point Name (APN) (e.g. the name of the ISP: isp1.de) to which the PS connection should be established to the SGSN

2) After the authentication and activation of the encryption the SGSN starts a query to the network internal DNS-server; this DNS-server returns the (network-internal) IP-address of the GGSN, which has a connection to the ISP that is specified by the APN

3) The SGSN requests the setup of a GTP tunnel for the subscriber data between SGSN and GGSN and informs the GGSN about the APN ("Create PDP Context Request")

4) The GGSN recognizes the ISP by means of the APN and allocates an (dynamic) IP address out of the IP address pool of the ISP to the subscriber (in case the MS has no fixed IP address)

5) The GGSN acknowledges the tunnel setup and sends the subscriber IP address to the SGSN ("Create PDP Context Response")

6) The SGSN requests the allocation of BSS resources and the setup of a SNDCP-tunnel for the subscriber data between SGSN and BTS

7) The BSC acknowledges the allocation of BSS resources and the SNDCP-tunnel setup

8) The SGSN acknowledges the setup of a PS connection to the MS and sends the subscriber IP-address to the MS ("Activate PDP Context Accept"); now data exchange with the Internet is possible

Routing of PS Connections
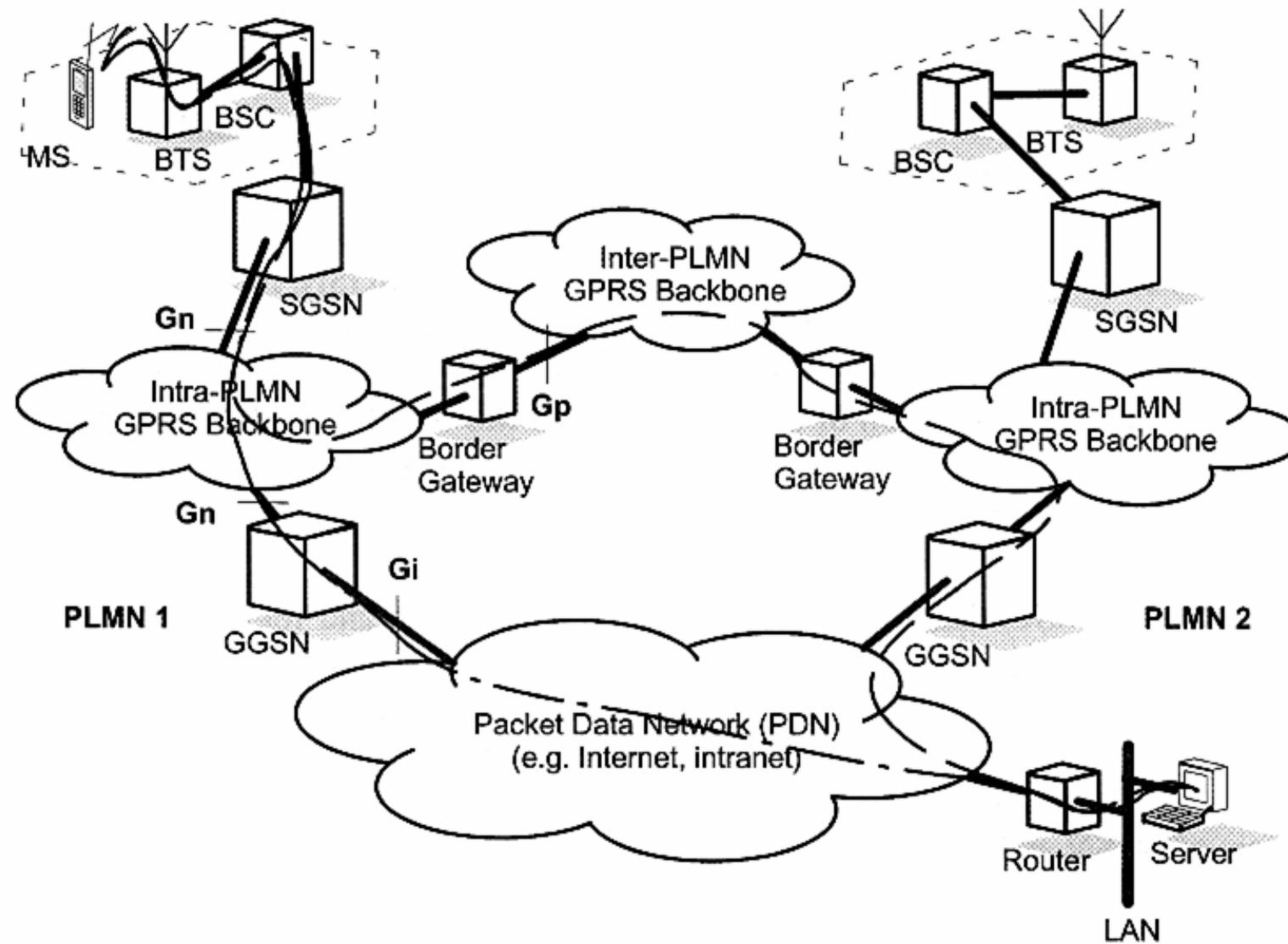
# CS Connection Setup from mobile to fixed Network (MOC*)

*MOC = Mobile Originating Call
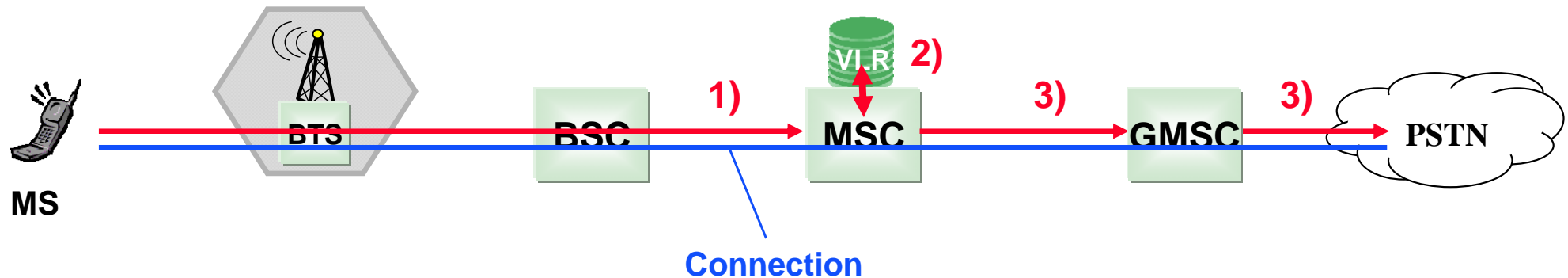
1) The MS sends CS connection setup request to the MSC

2) Before the MSC accepts the connection setup request, it performs an authentication (by querying the VLR) and activates the encryption

3) After the successful assignment of resources, the connection request is forwarded to the subscriber in the PTSN according to the dialed phone number; the phone rings and after the PTSN subscriber hooks off, the connection is established

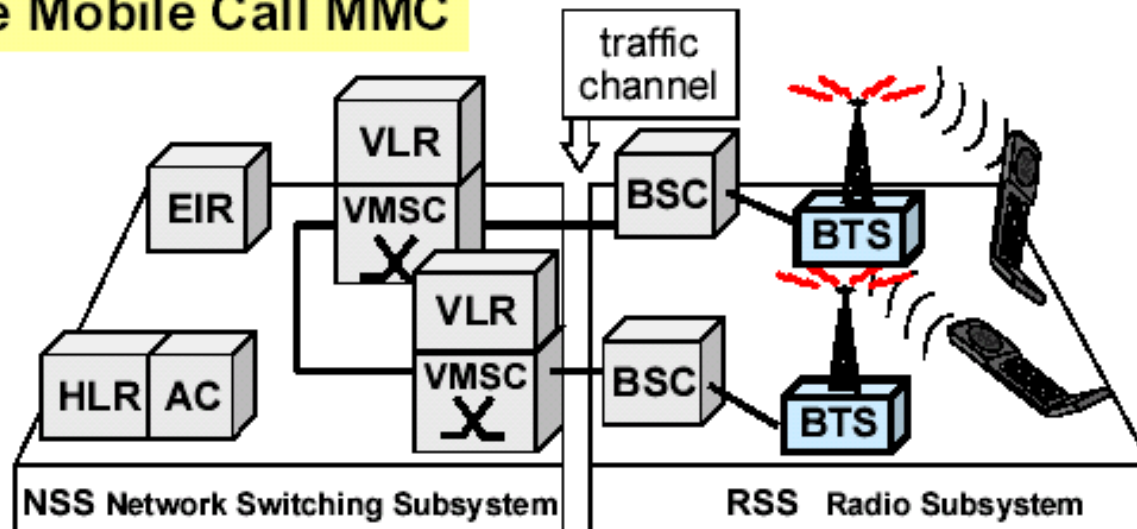# CS Connection Setup form fixed to mobile Network (MTC*)
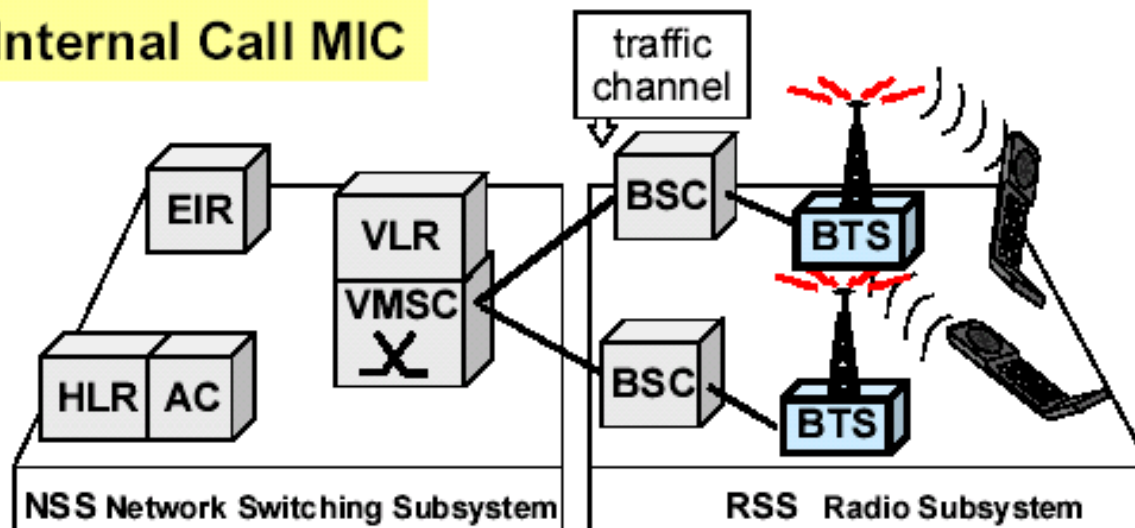
*MTC = Mobile Terminating Call
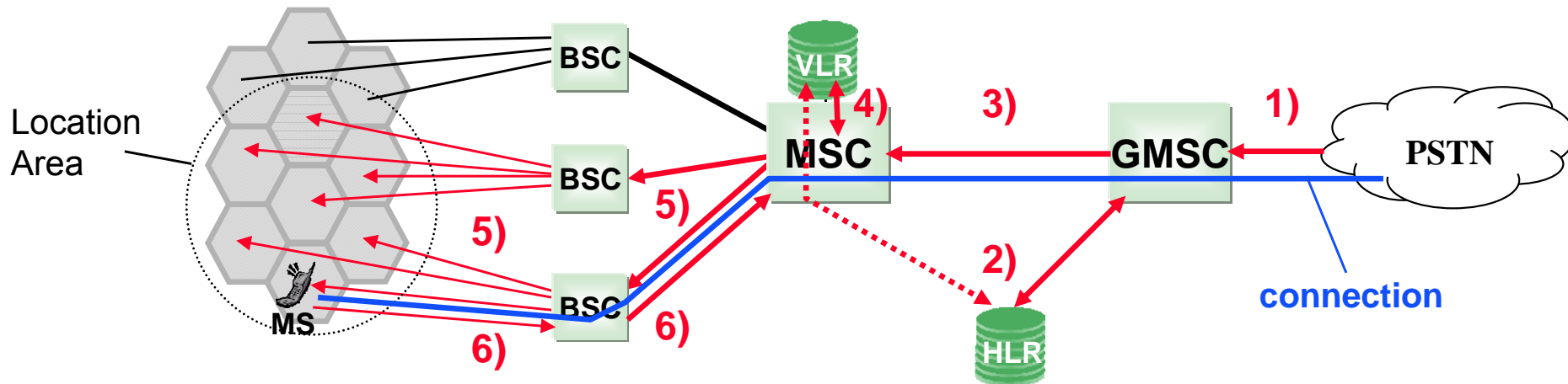
1) The PSTN recognizes through the phone number (MSISDN), that the connection is destined towards a mobile network and routes the connection to a GMSC in the Home PLMN of the called subscriber

2) The GMSC queries the HLR (MSISDN→MSRN) to determine the MSC which currently serves the MS (MSC Area) (possibly the HLR also has to query the VLR)

3) The connection is forwarded to this MSC

4) The MSC queries the VLR to determine the location area in which the MS is located

5) The MS is paged in all cells belonging to this location area (Paging)

6) The MS responses (Paging Response); after authentication and activation of the encryption, resources are assigned and the incoming call is signaled at the MS ("ringing"); after off-hooking the phone, the connection is established

# CS Connection Setup within a mobile Network

Mobile Mobile Call MMC

traffic channel

VLR
EIR
VMSC
VLR
HLR AC
VMSC
BSC
BTS
BSC
BTS

NSS Network Switching Subsystem

RSS Radio Subsystem

Mobile Internal Call MIC

traffic channel

EIR
VLR
VMSC
HLR AC
BSC
BTS
BSC
BTS

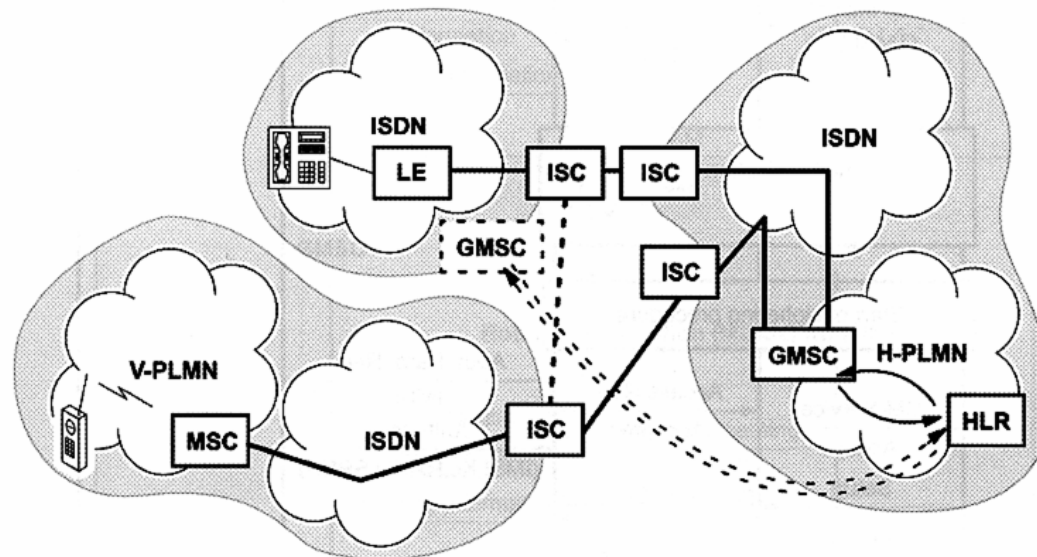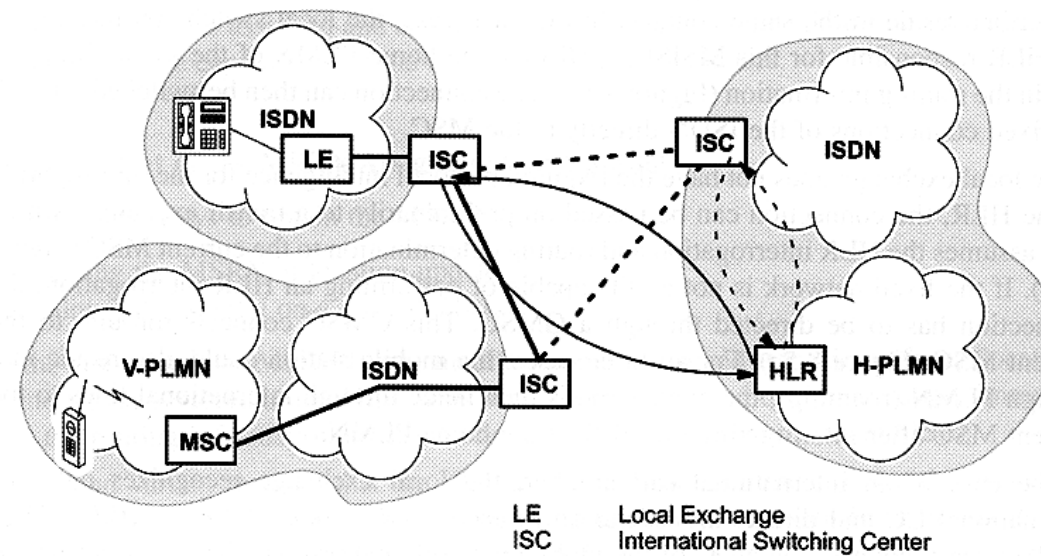NSS Network Switching Subsystem

RSS Radio Subsystem

- For **MMC**, MOC and MTC take place successively
- The MSC recognizes, that the connection is within the own mobile network and queries the HLR to determine the MSC area in which the MS is located. The connection is then forwarded to the corresponding MSC
- **MIC** is a special case of MMC where the calling and called MS are in the same MSC area
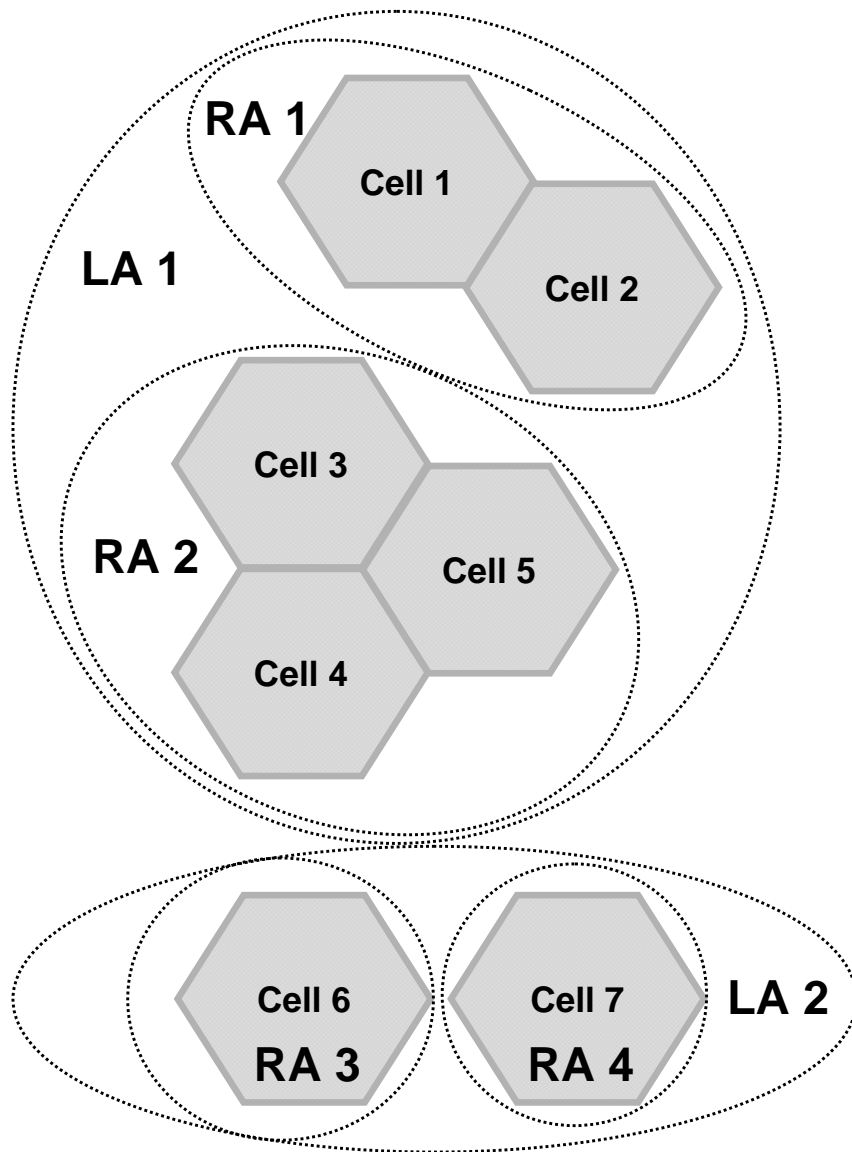
MTC Routing Options for national CS Connections

LE — Local Exchange
TE — Transit Exchange
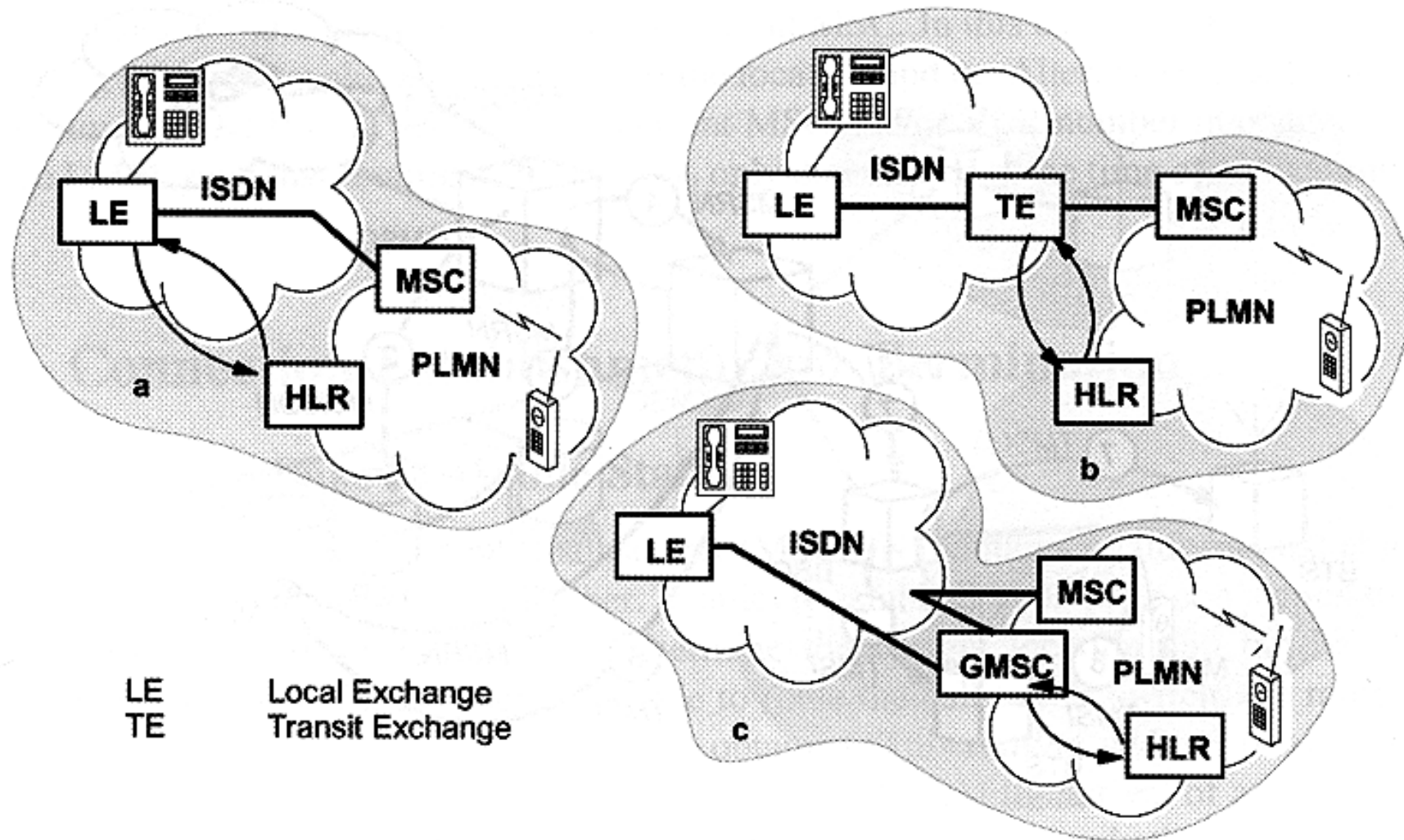
MTC Routing Options for international CS Connections

LE   Local Exchange
ISC   International Switching Center

GSM Mobility Management

Localization Areas: Location Areas and Routing Areas

RA 1

Cell 1

LA 1

Cell 2

Cell 3

RA 2

Cell 5

Cell 4

Cell 6

RA 3

Cell 7

RA 4

LA 2

Location Area (LA):

- localization area that consists of one or more cells for **CS services**
- explicitly assigned to a **MSC/VLR**
- can contain one or more RAs

Routing Area (RA):

- localization area that consists of one or more cells for **PS services**
- explicitly assigned to a **SGSN**
- smaller or equal to a LA

State-dependent Mobility Functions

Attached (without active con.)

MS is switched-on and attached, but there are **no active connections**

Knowledge of the location:
- CS: location area
- PS: cell (MM-READY) or routing area (MM-STANDBY)

Mobility control through:
- MS

Procedures (MS):
- reporting the current location:
  - CS: LA-Update to MSC*
  - PS: Cell-Update (MM-READY) or RA-Update (MM-STANDBY)
- Cell Reselection (cell change)

    * periodically or in case of move into a new RA/LA

Active Connections

MS is switched-on, attached and **CS or active PS connections** exist (active PDP context, MM-READY)

Knowledge of the location:
- cell

Mobility control through:
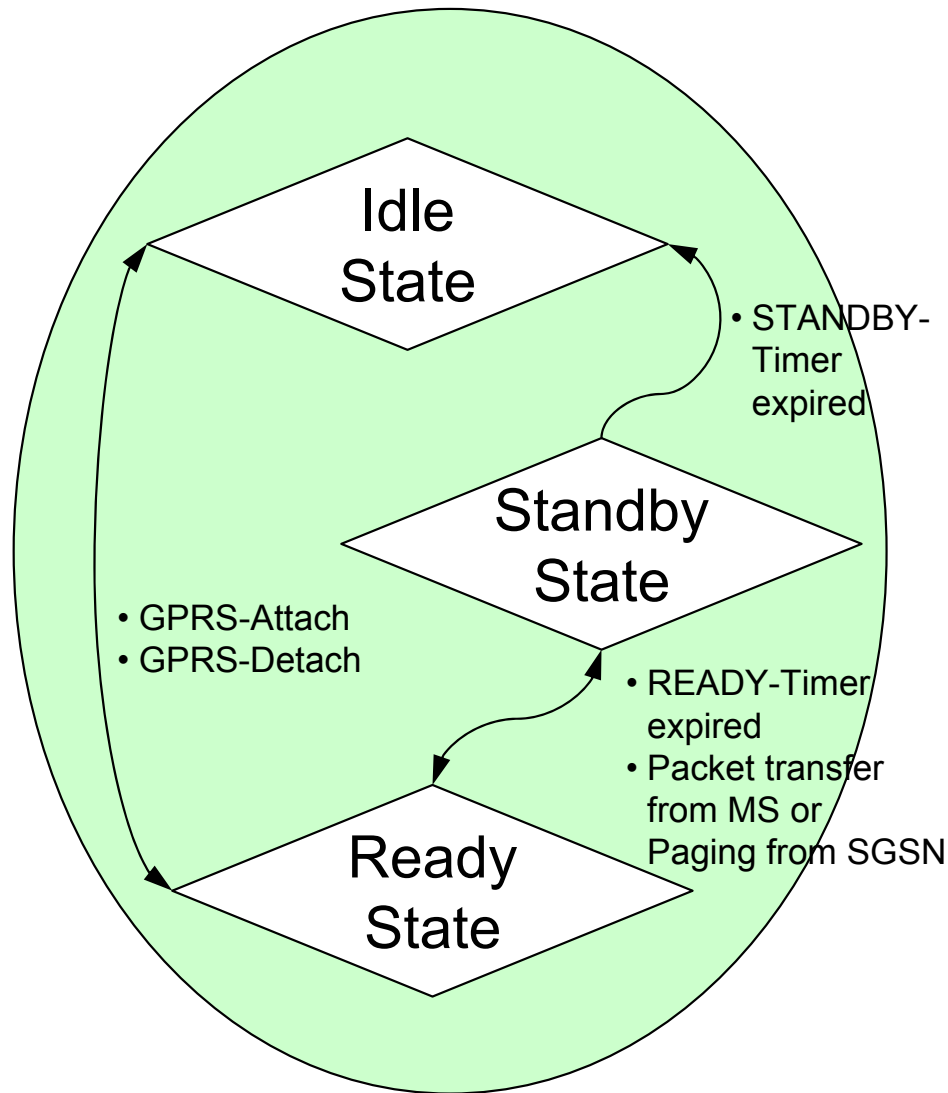- CS: network
- PS: MS

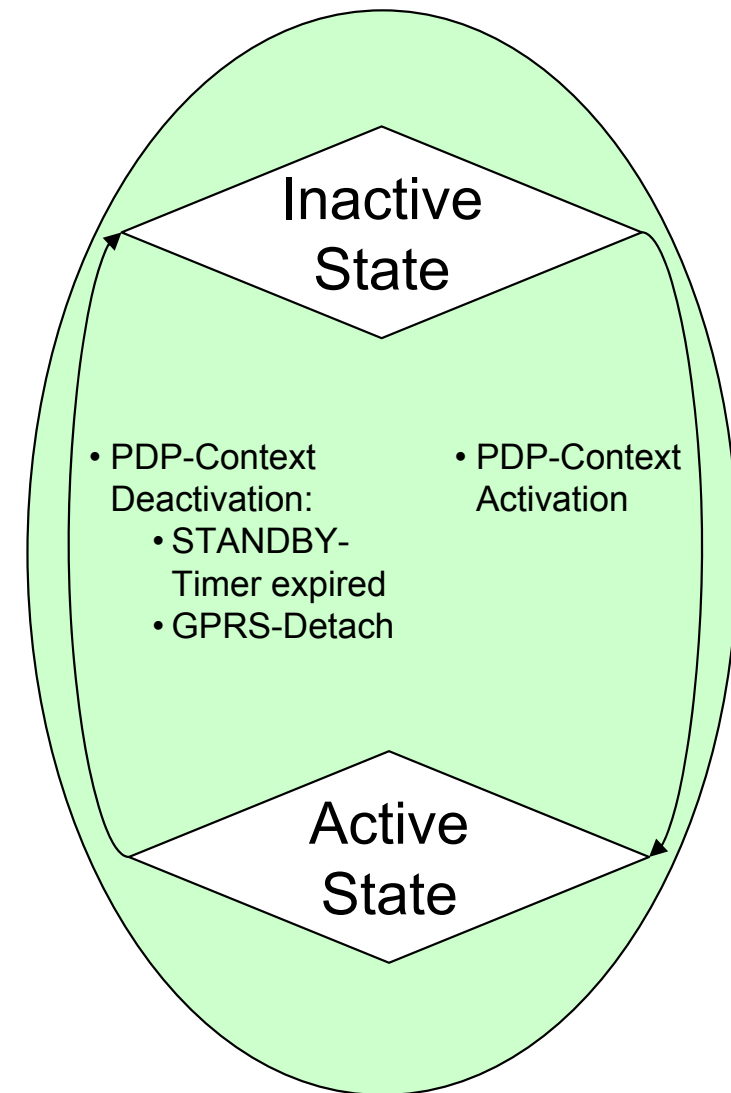Procedures (network) - CS only:
- handover control

Procedures (MS) - PS only:
- reporting the current location: Cell-Update to the SGSN
- Cell Reselection (cell change) possibly network-assisted
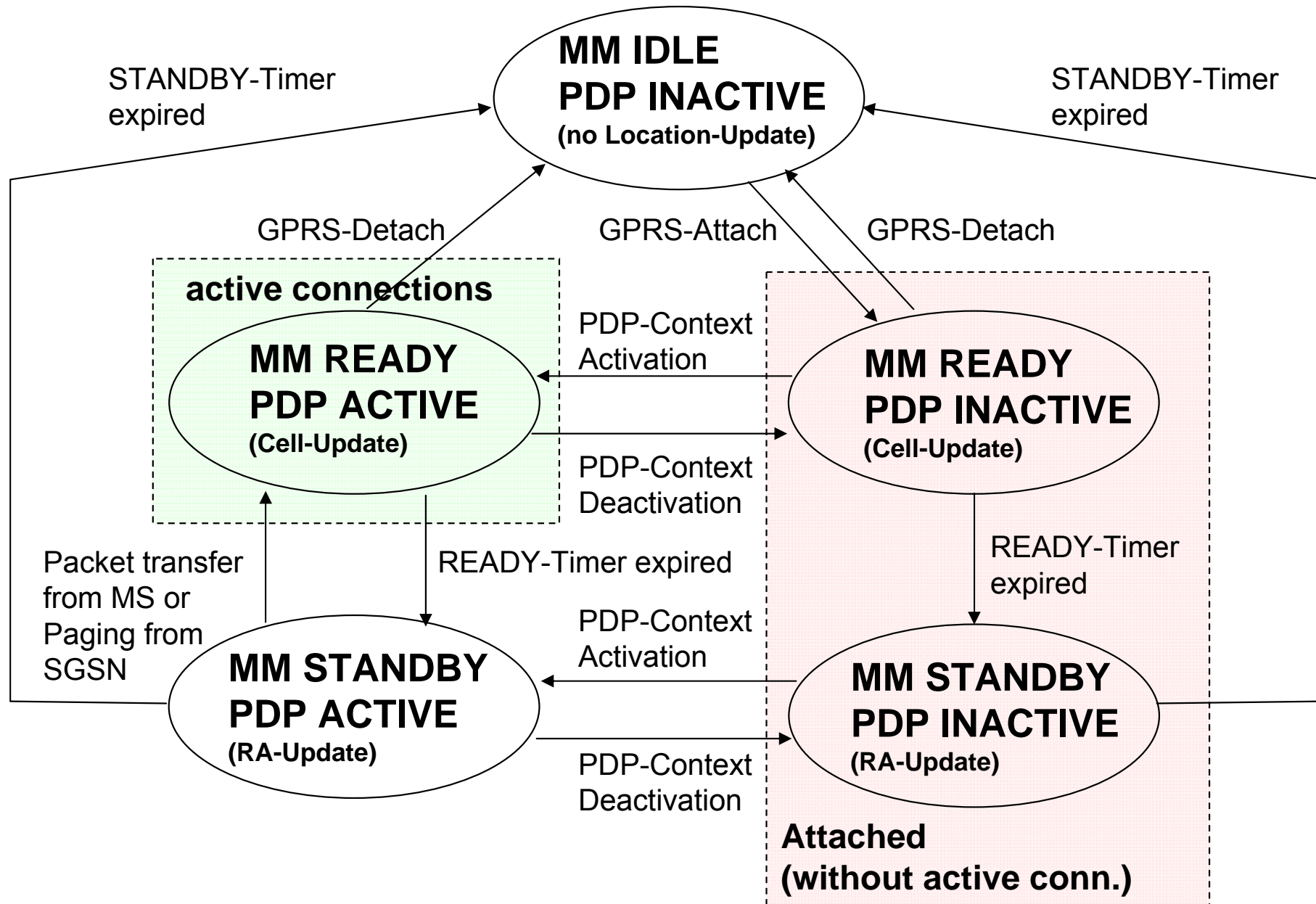
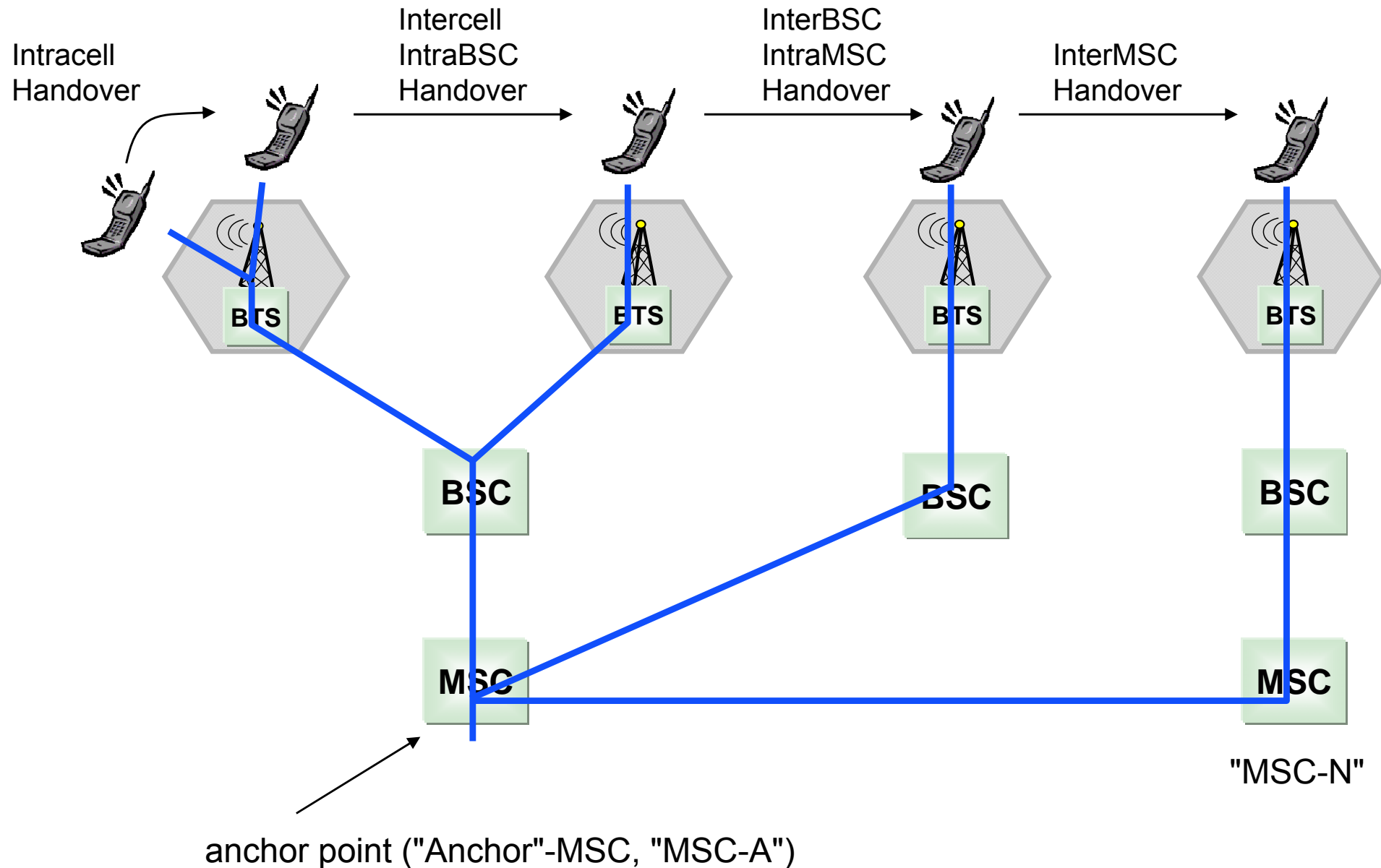# MM and PDP States for PS Services (GPRS)

Mobility Management (MM) States

Packet Data Protocol (PDP) States

States for PS Services (GPRS) - MM & PDP combined

Handover Options for CS Connections

Intracell
Handover

Intercell
IntraBSC
Handover

InterBSC
IntraMSC
Handover

InterMSC
Handover

BTS

BTS

BTS

BTS

BSC

BSC

BSC

MSC

MSC

"MSC-N"

anchor point ("Anchor"-MSC, "MSC-A")

Handover Options for CS Connections

1. Intra-Cell Handover
   - for administrative reasons or because of channel selective interference
   - assignment of a new frequency channel
   - locally controlled through the RRM of the BSS (within BSC)

2. Inter-Cell, Intra-BSC Handover
   - in case of cell change due to mobility or for distributing the traffic load between cells
   - locally controlled through the RRM of the BSS (within BSC)
   - the MSC is informed about the completed handover

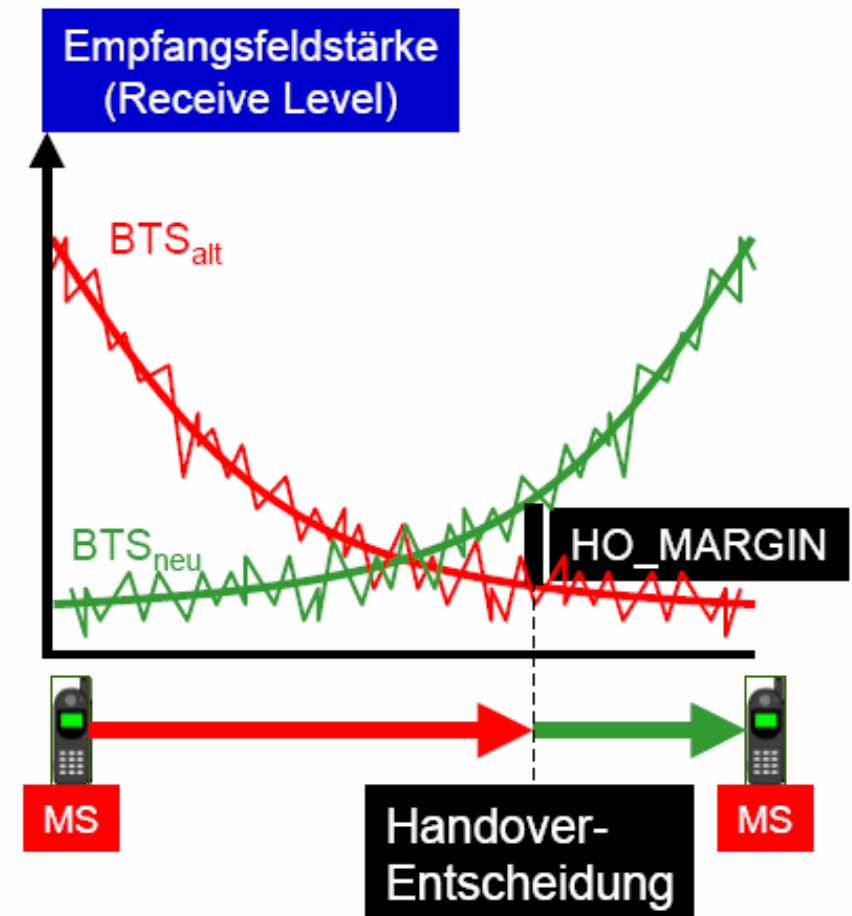3. Inter-BSC, Intra-MSC Handover
   - the old BSS (BSC) sends a handover request to the MSC
   - the MSC decides about the target BSS and controls the handover
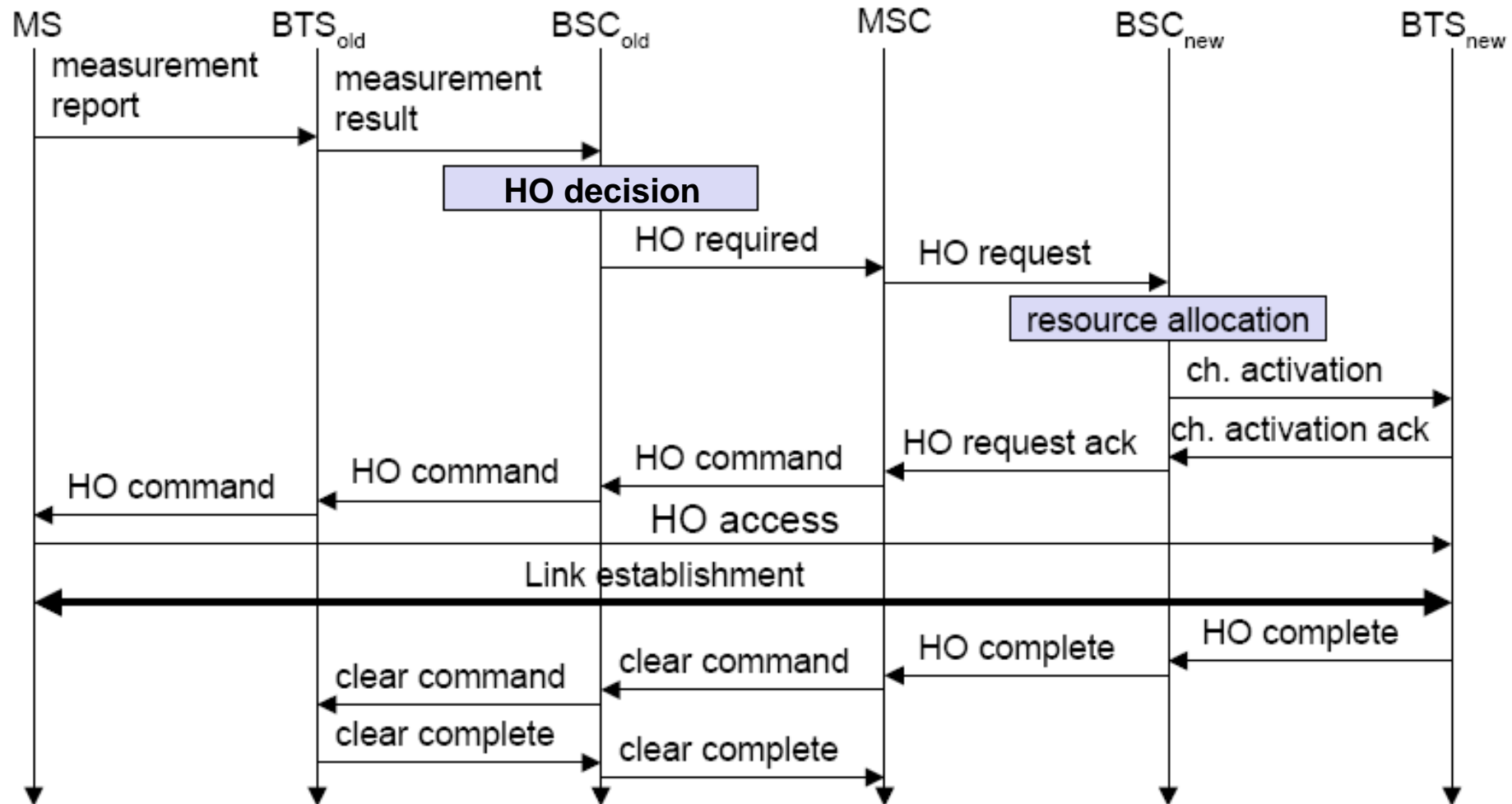
4. Inter-MSC Handover
   - two MSCs (MSC-A und MSC-N) coordinate the handover
   - the original MSC (MSC-A) keeps control of the connection for the whole connection lifetime (Anchor-MSC, MSC-A); the connection is only extended to the MSC-N

Handover Decision

- The network (MSC) performs the hand-over decision (network originated HO)
  - advantage: the network operator may develop and use own optimized handover algorithms
- Handover decision sequence:
  - BTS and MS measure the quality of uplink and downlink direction: received field strength (of own and neighboring cells) and bit error rate
  - the MSC compares the measured values with thresholds (handover margin, HO_MARGIN) and initiates a handover if the threshold is reached
  - remark: a hysteresis is applied to avoid ping pong handover effects

Handover Signaling (Example: InterBSC, IntraMSC HO)

Updating PS Connections (≠ seamless Handover)

Intra-SGSN Update (Micro Mobility)   Inter-SGSN Update (Macro Mobility)
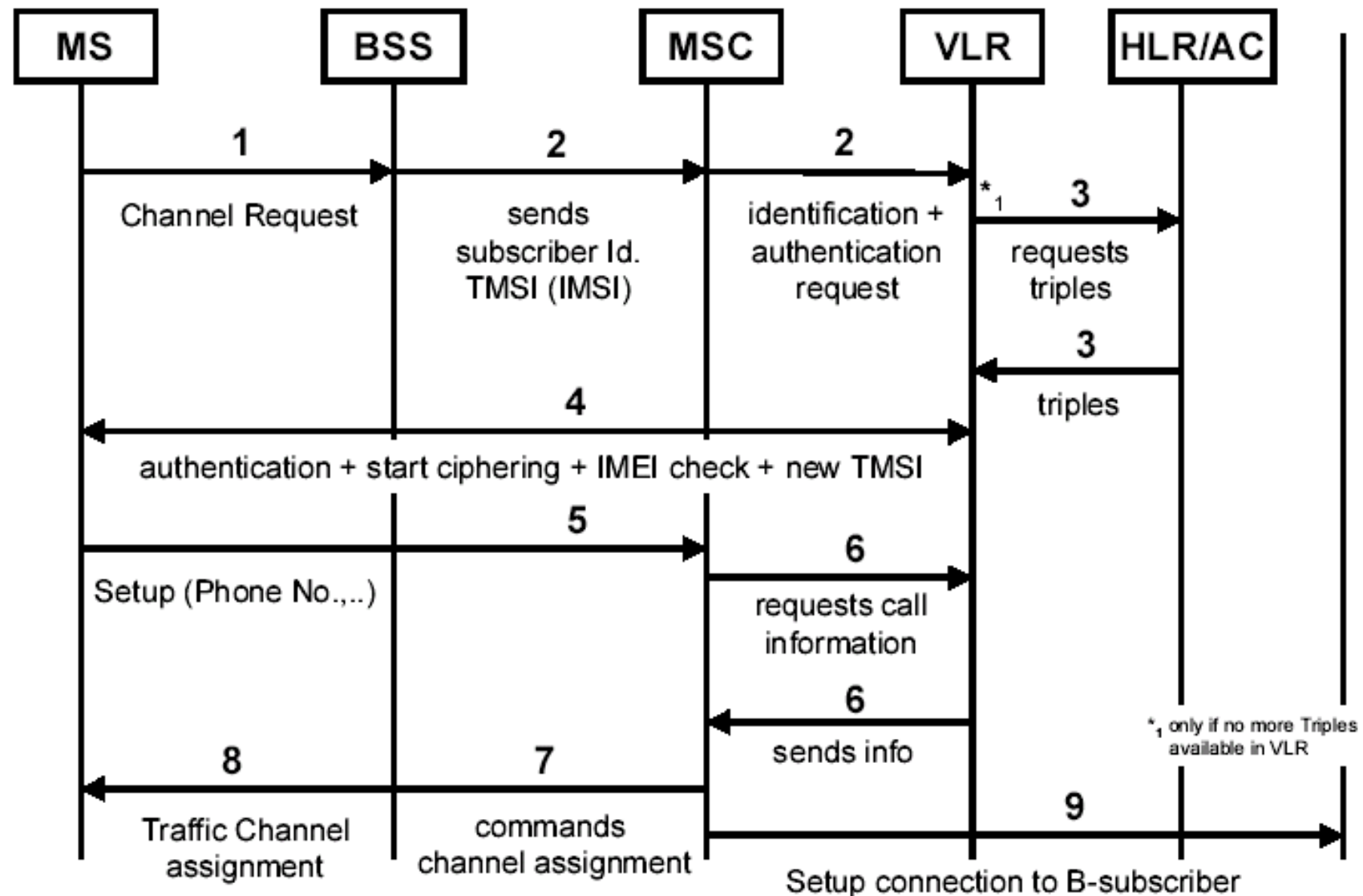
SNDCP-Tunnel

GTP-Tunnel

GGSN = anchor point
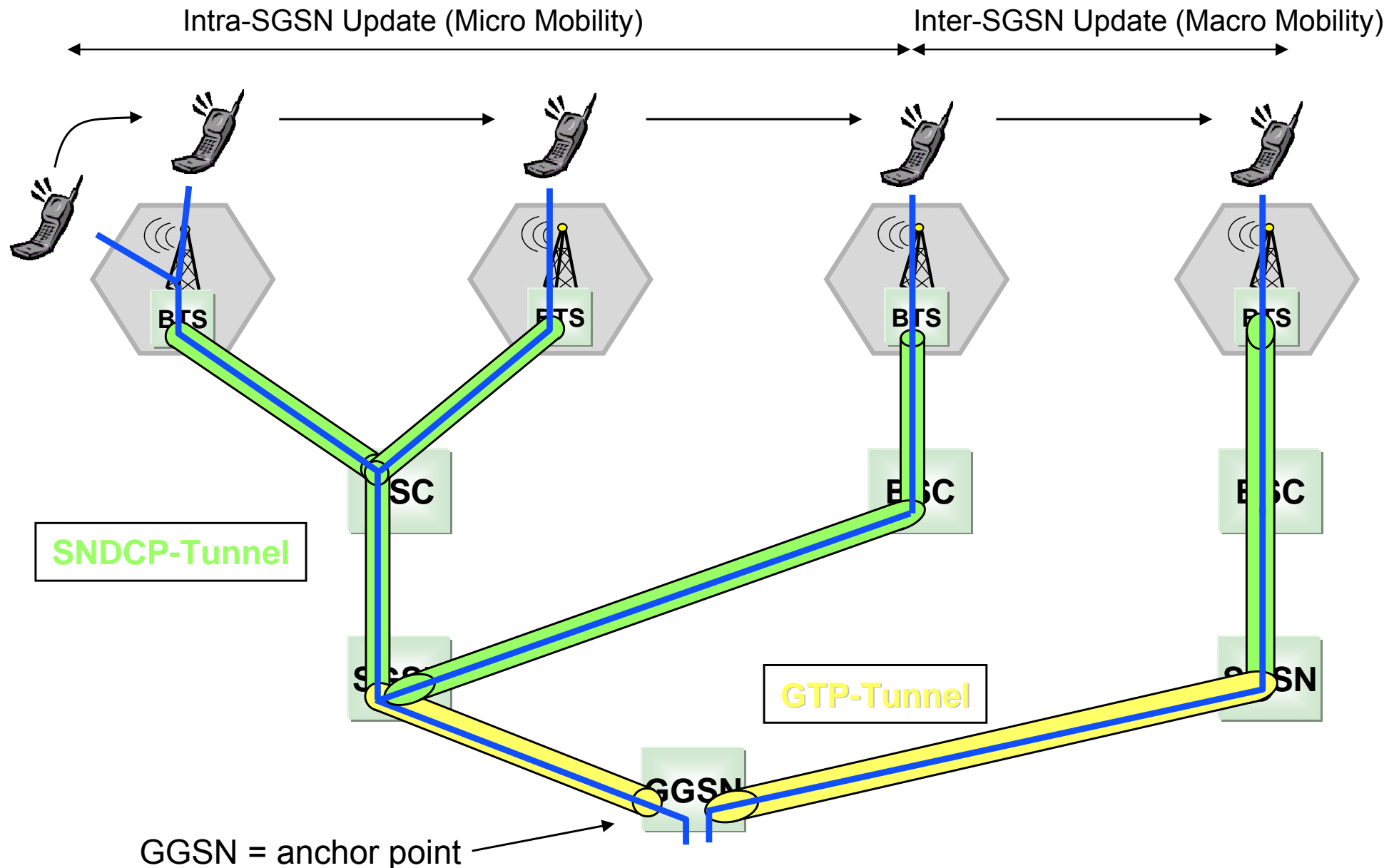
Annex
Details

CS Connection Setup from mobile to fixed Network - MOC

CS Connection Setup from mobile to fixed Network - MOC

1. Channel Request: The MS requests for the allocation of a dedicated signaling channel to perform the call setup.

2. After allocation of a signaling channel the request for MOC call setup, included the TMSI (IMSI) and the last LAI, is forwarded to the VLR

3. The VLR requests the AC via HLR for Triples (if necessary).

4. The VLR initiates Authentication, Cipher start, IMEI check (optional) and TMSI Re-allocation (optional).

5. If all this procedures have been successful, MS sends the Setup information (number of requested subscriber and detailed service description) to the MSC.

6. The MSC requests the VLR to check from the subscriber data whether the requested service an number can be handled (or if there are restrictions which do not allow further proceeding of the call setup)

7. If the VLR indicates that the call should be proceeded, the MSC commands the BSC to assign a Traffic Channel (i.e. resources for speech data transmission) to the MS

8. The BSC assigns a Traffic Channel TCH to the MS

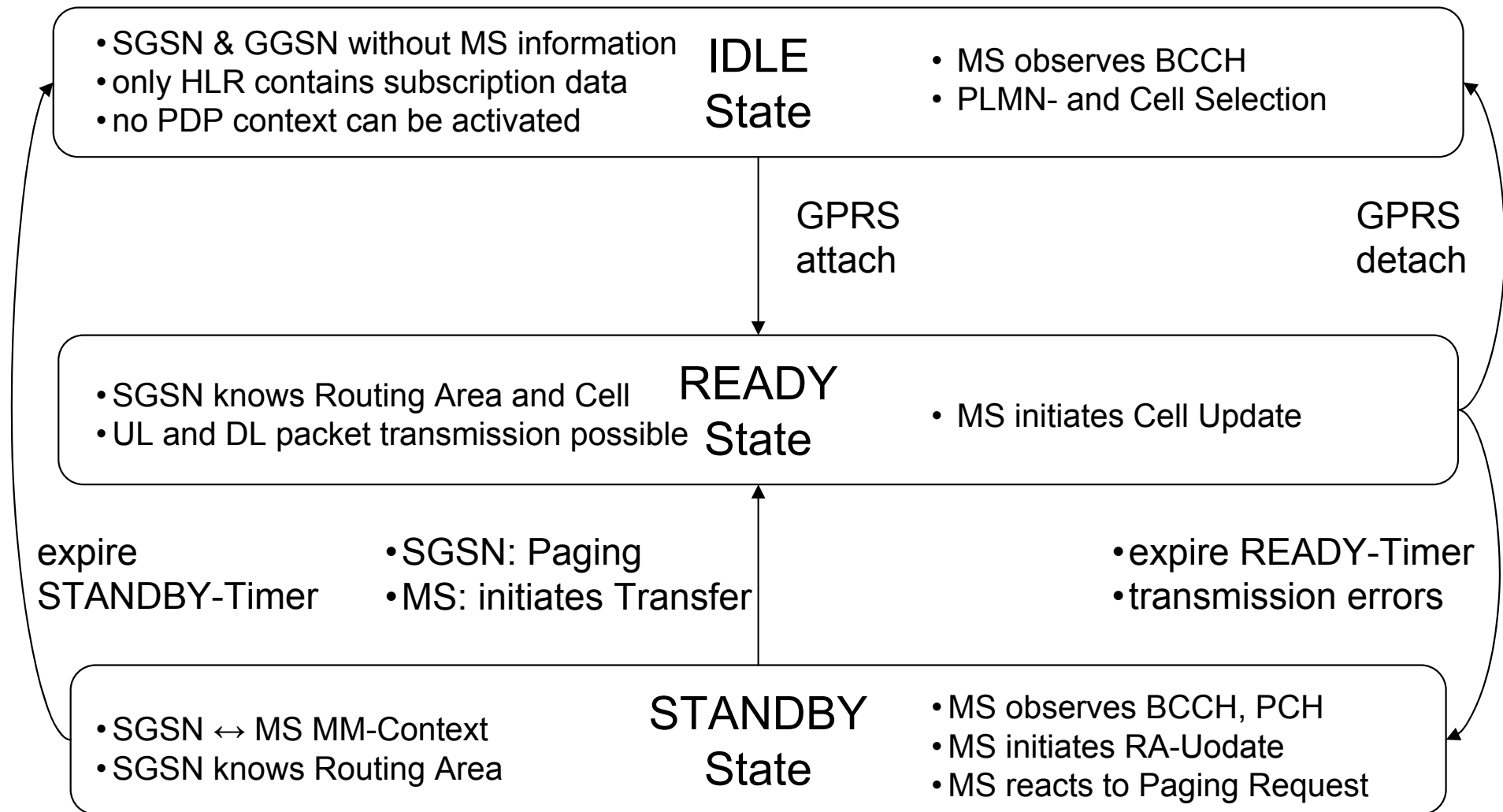9. The MSC sets up the connection to requested number (called party).

CS Connection Setup from fixed to mobile Network - MTC
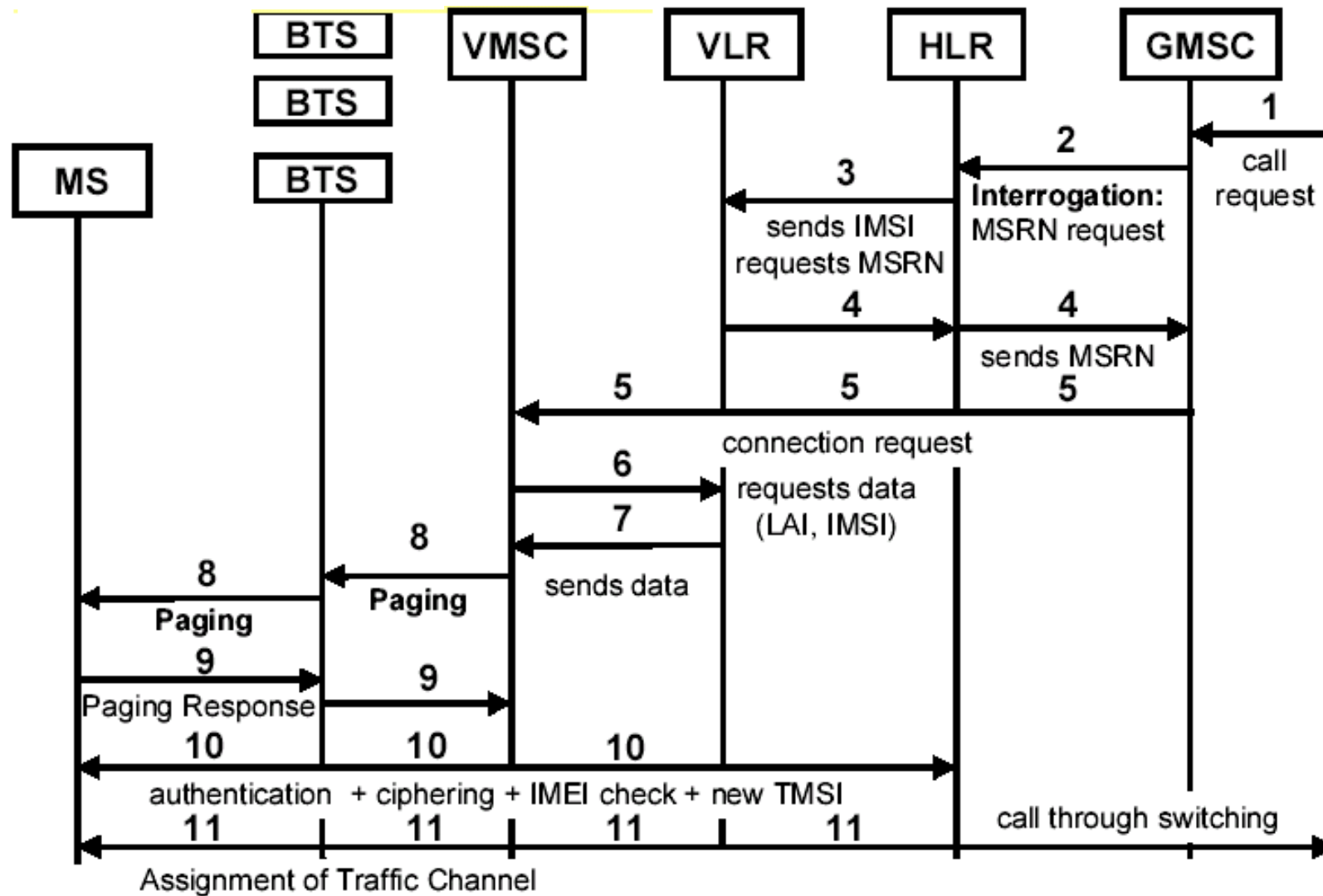
CS Connection Setup from fixed to mobile Network - MTC

1. After analysis of the MSISDN (CC and NDC) a request to set up a call is transmitted from an external exchange to the GMSC.

2. The GMSC identifies the users HLR from the MSISDN. It starts a so-called Interrogation to the HLR to get information of the subscribers current location.

3. The HLR identifies the subscribers IMSI from the MSISDN and checks the subscribers current location, i.e. the VLR address. The HLR informs the VLR about the call and requests a Mobile Station Roaming Number MSRN (including the VMSC address) from the VLR. The request to the VLR includes the LMSI, which enables the fast access to the users data in the VLR.

4. The VLR transmits the MSRN to the HLR, which forwards this number and the IMSI to the GMSC. If the VLR has information, that the MS is Detached currently, the call is rejected / forwarded to the Mailbox.

5. The GMSC uses the MSRN (including the VMSC address) and IMSI to get into contact with the VMSC.

6. The VMSC requests information (LAI, TMSI) for call setup from its VLR

7. The VLR sends these data.

8. The VMSC uses the LAI to start the Paging procedure. Paging means to search to MS in the total Location Area (the precise cell is not known).

9. The MS responses the Paging, i.e. from now on its cell is known.

10. This topic includes: Authentication, cipher start, IMEI check and TMSI Re-allocation.

11. The MSC transmits the Setup information to the MS, commands the BSC to allocate a Traffic Channel to the MS and switches through the connection.

Mobility Management States for PS Services (GPRS)

IDLE State
- SGSN & GGSN without MS information
- only HLR contains subscription data
- no PDP context can be activated
- MS observes BCCH
- PLMN- and Cell Selection

GPRS attach

GPRS detach

READY State
- SGSN knows Routing Area and Cell
- UL and DL packet transmission possible
- MS initiates Cell Update

expire STANDBY-Timer

- SGSN: Paging
- MS: initiates Transfer

- expire READY-Timer
- transmission errors

STANDBY State
- SGSN ↔ MS MM-Context
- SGSN knows Routing Area
- MS observes BCCH, PCH
- MS initiates RA-Uodate
- MS reacts to Paging Request

Mobility Management States for PS Services (GPRS)

IDLE State:

A mobile station MS in the idle state is detached from the GPRS. Only GPRS subscription data is available in the HLR. No further information exists in other network units such as SGSN and GGSN. It is not possible to activate a packet data protocol PDP or to maintain a PDP in its active state. The GPRS MS must monitor the BCCH to determine the availability of cells which support GPRS services. Accordingly, the GPRS MS can carry out PLMN and cell selection procedures. To exit idle state, the MS must execute the "attach" procedure. Upon successful completion of this procedure, the MS changes to ready state.
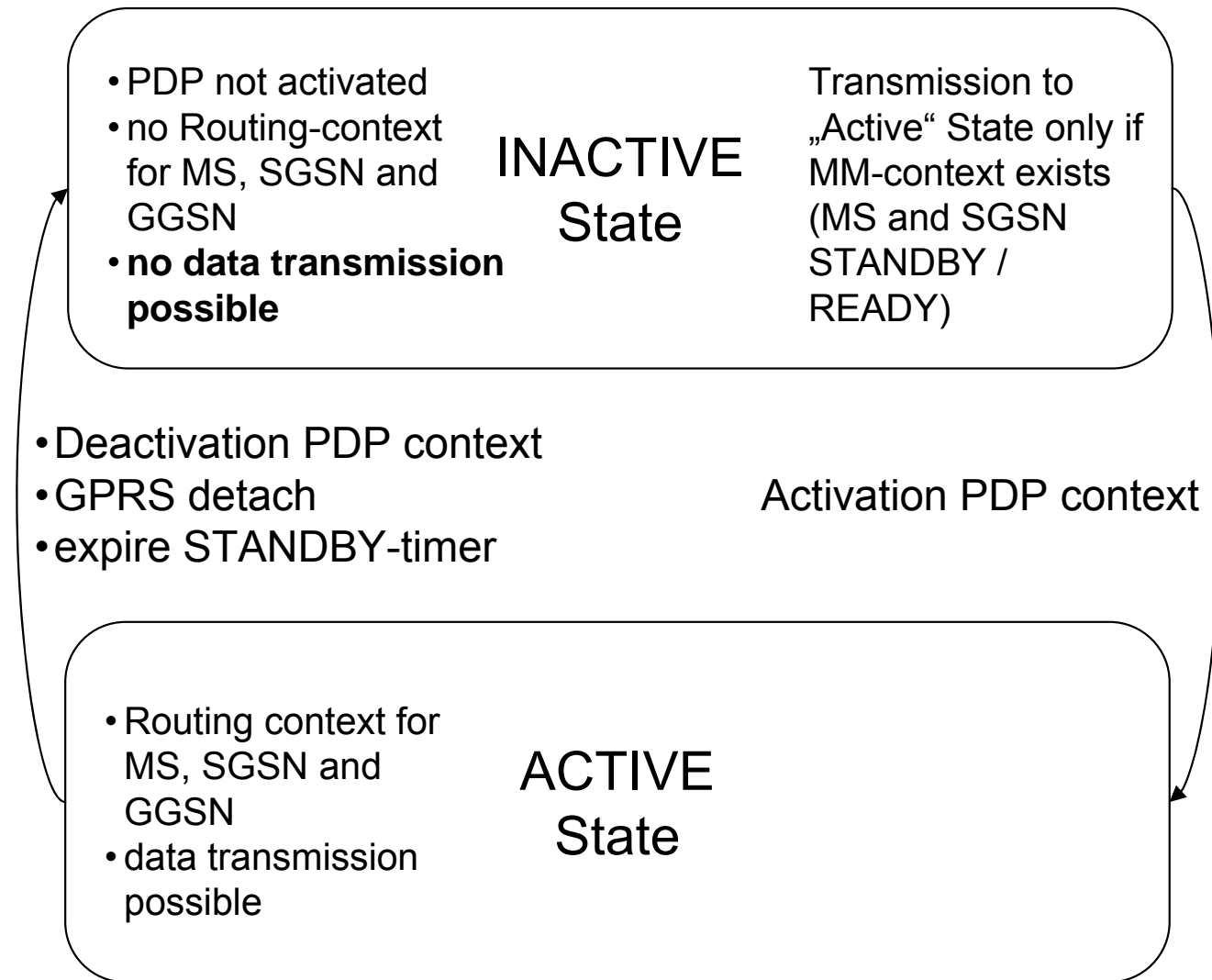
STANDBY State:

In the standby state the GPRS MS is attached to the GPRS network. The GPRS and the SGSN have a mobility management context comparable to the circuit switched connections. The MS monitors the broadcast channel to determine the availability of cells offering GPRS services and also the paging channel PCH, to be informed about paging requests. The SGSN recognizes/stores the routing area RA of the GPRS-MS. The routing area is a sub-unit of the location area LA, in other words a more detailed determination of the GPRS-MS location. The GPRS-MS informs the SGSN about changes of the routing area and answers paging requests.

READY State:

In the ready state, the SGSN detects the current cell of the GPRS-MS beyond the routing area RA of the GPRS-MS. If the GPRS-MS changes cells, it informs the SGSN. Paging is thus superfluous in the ready state. The DL packet data transfer can be performed any time. Ready state does not mean that a physical connection is established between SGSN and MS. Only in the ready state, SGSN and MS can transfer data packets. MS and SGSN exit ready state upon expiry of a ready timer or in case of a faulty packet data transmission and change to standby state. Upon log-off, i.e. execution of a detach procedure, MS and SGSN exit ready state and change to idle state.

PDP States for PS Services (GPRS)

INACTIVE
State

- PDP not activated
- no Routing-context for MS, SGSN and GGSN
- **no data transmission possible**

Transmission to „Active" State only if MM-context exists (MS and SGSN STANDBY / READY)

- Deactivation PDP context
- GPRS detach
- expire STANDBY-timer

Activation PDP context

ACTIVE
State

- Routing context for MS, SGSN and GGSN
- data transmission possible

PDP States for PS Services (GPRS)

"Inactive" State

The inactive state of a PDP means that this PDP is not operating at that moment. There is no routing context in the MS, SGSN and GGSN. A transition in the active state is only possible if there is a mobility management connection and if MS and SGSN are in the standby or ready state.

No data transfer is possible in the inactive state. Data packets which reach the GPRS network are either rejected or ignored.

"Active" State

In the active state the MS, GGSN and SGSN are in a routing context. Data can be transmitted or received by the MS. The active state is ended explicitly if the MS de-activates a certain PDP. With GPRS detach and expiry of the standby timer, all the activated PDP are deactivated, too.