GSM Network Architecture, Channelisation, Signalling and Call Processing

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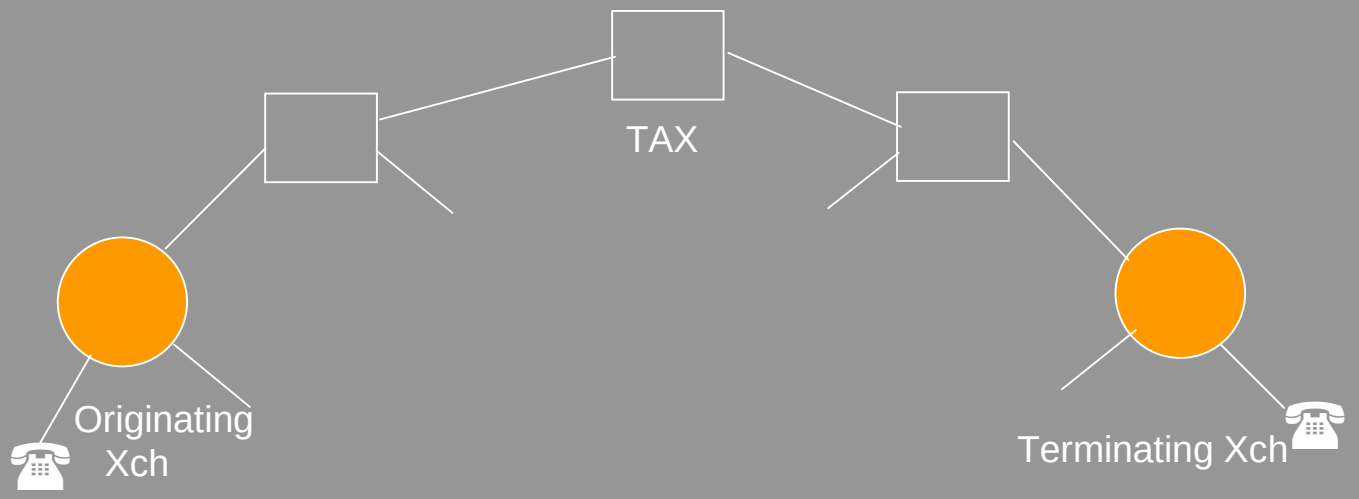
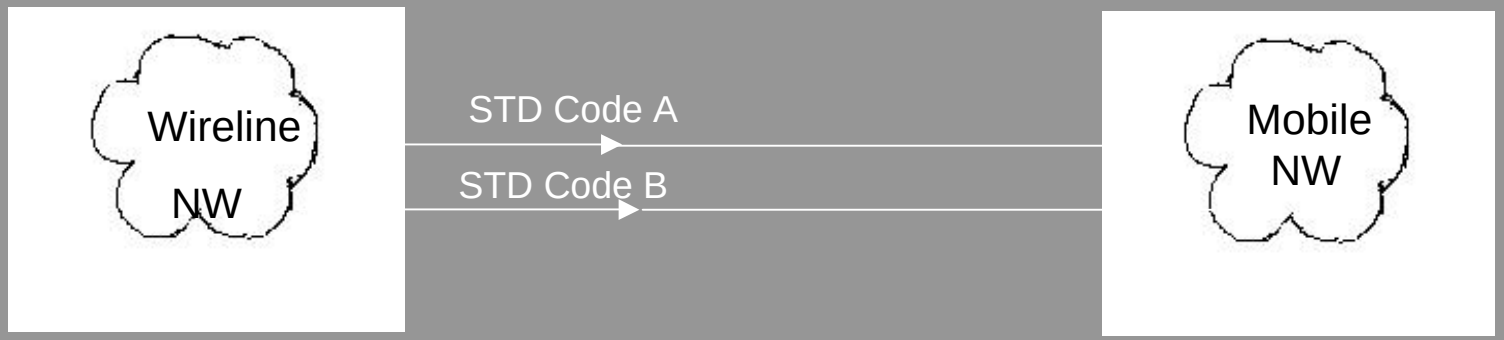
Call Routing in Wireline Network

- location of exchange port corresponding to each number fixed
  - ⇨ incoming calls to a number have to be routed to a particular exchange
- routing based on number analysis by originating exchange and intermediate exchanges
  - ⇨ call routed hop by hop



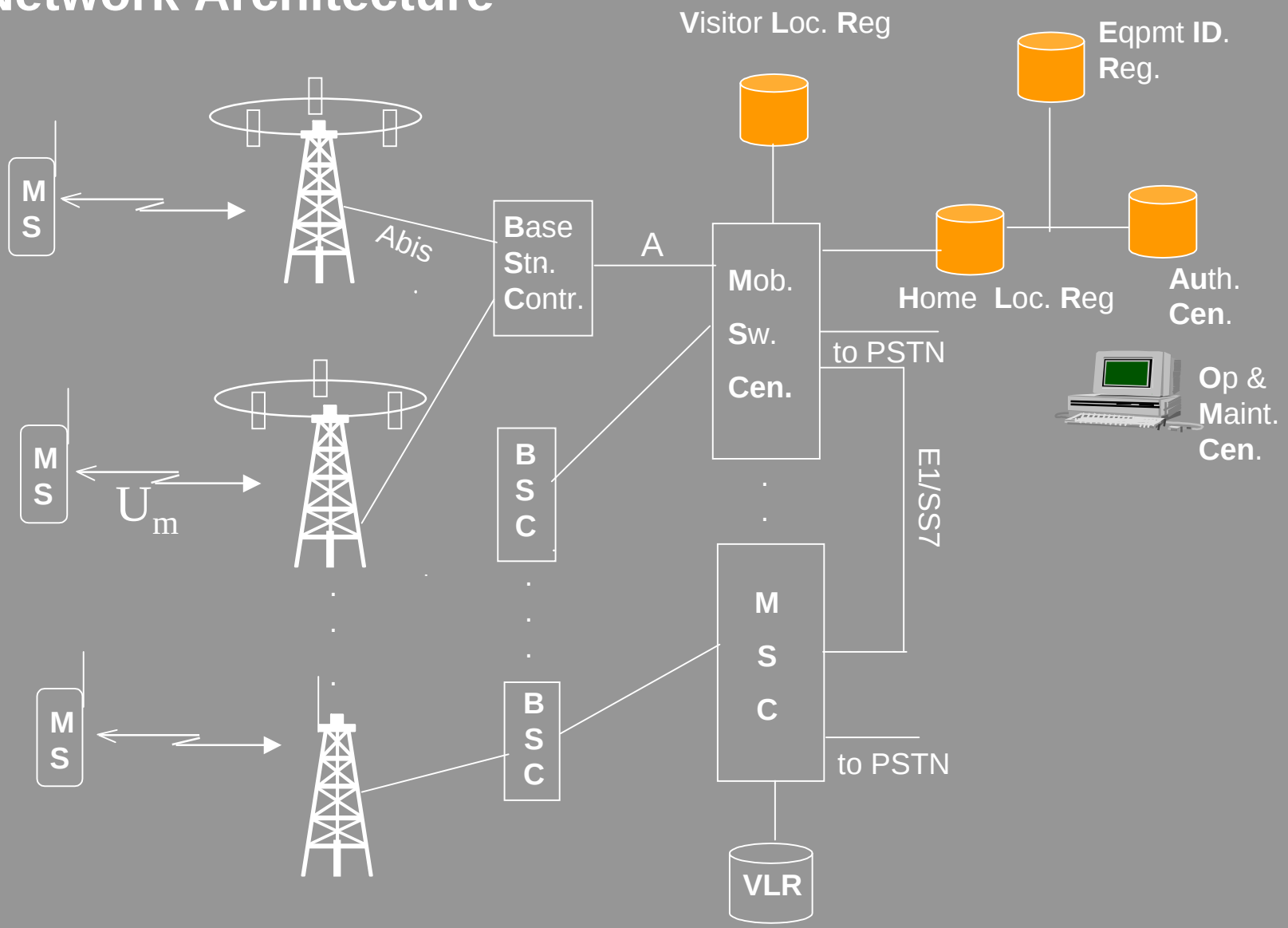
Call Routing To and From Mobile Network

- Location of mobile telephone not fixed
  - tracked by mobile network (MN)
    - ⇨ MN must accept incoming calls at one (or more) fixed exchanges (called **gateway**)
    - ⇨ routing of call to mobile handled by MN
    - ⇨ subequent routing due to movement of mobile handled entirely by MN
      - handovers
- all calls to mobiles with a particular prefix routed to one interconnect point



- outgoing calls can be routed to Interconnect Point nearest the called subscriber

Network Architecture



GSM Subsystem Functions

- **MS:** voice, short messages, terminal adapter for fax/modem
  - **S**ubscriber **I**dentity **M**odule is the subscriber's personality

    ⇨ handset is "faceless"

- **BTS:** radio endpoint
  - may, or may not, have 13/5.6 kbps ⟷ 64 kbps transcoders

    ⇨ transcoders may be at BSC or MSC
- **BSC:** controls one or more BTSs
  - channel assignment, handover, power control
- **MSC:** controls BSCs, interface to PSTN, databases

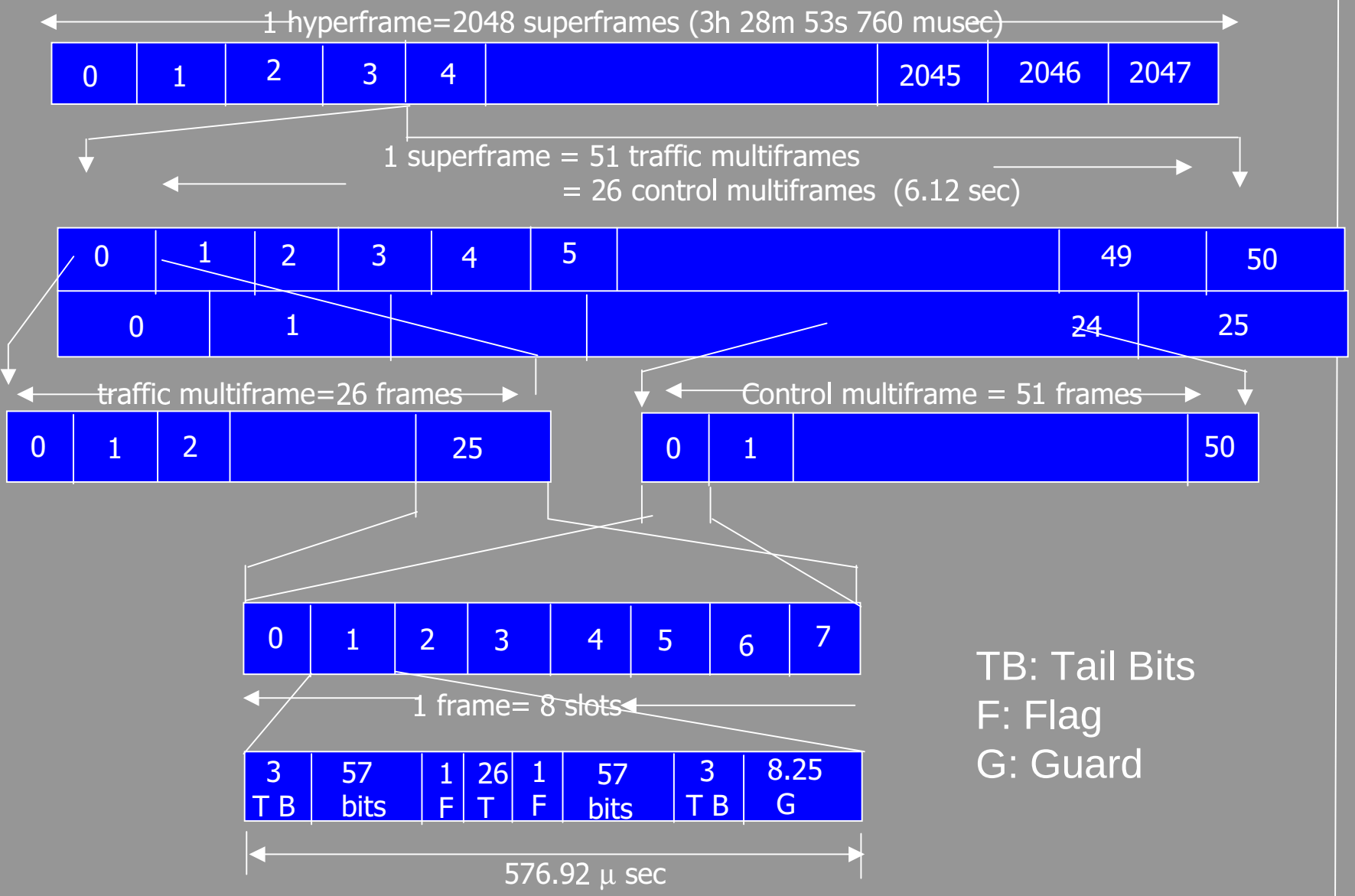
Physical vs Logical Channels on Air Interface

- Physical Channels :
  - one or more time slots in
    - every TDMA frame (e.g. speech data)
    - periodic frames (e.g. signalling)
    - random frames (e.g. call set up)
  - can be
    - dedicated to one mobile
    - shared by many mobiles
- Logical Channels : pathways created on physical channel for data flow between mobile and other entities of MN
  - **traffic** channel (carries user payload - speech, data)
  - **signalling** channel
    - broadcast
    - common control
    - dedicated control

Multiframe Structure

- 8 time slots per carrier : 576.92 μs x 8 = 4.615 ms frame duration
  - slot 0 on one carrier (called **beacon**) is for control
  - 156.25 bits/slot
- control slot multiframe = **51** frames
- traffic slot multiframe = **26** frames (120 msec)
- superframe = 26 x 51 frames (6.12 sec)
- hyperframe = 2048 superframes (~ 3.5 hours)

Multiframe Structure (Contd.)



TB: Tail Bits
F: Flag
G: Guard

Traffic Channels: Full Rate/Half Rate (TCH/F and TCH/H)

- One slot in every frame of 26-multiframe except in frame numbers (FN) 12 and 25
  ⇨ 24 slots in 120 msec ⇨ 4 x 57 x 2 = 456 bits every 20 msec

- 13 kbps speech coder : 260 bits/20 msec ⟶ 456 bits with FEC

- half-rate: use alternate frames for one user
  ⇨ second user uses FN 25 for signalling (FN 25 is idle for first)

- 5.6 kbps coder : 112 bits/20 msec ⟶ 228 bits with FEC

- downlink frames offset by 3 slots to avoid simultaneous Tx/Rx in MS

Associated Control Channel (ACCH)

- 114 bits every 120 msec for signalling (in FN 12)
- [184 bits (23 bytes) message + 40 parity bits] x 2 due to convolutional code

  ⇨ 456 bits ⇨ 480 msec, or four 26 - multiframes

  – **S**low **ACCH** (~ 380 bits/sec)
- SACCH is associated with TCH

  ⇨ useful after TCH assigned to MS
- SACCH multiframes for different time slots are offset

  ⇨ load balancing at BSC
- for fast signalling (e.g. for handover), use **FACCH**

  – steal 57 bits from TCH in 8 slots

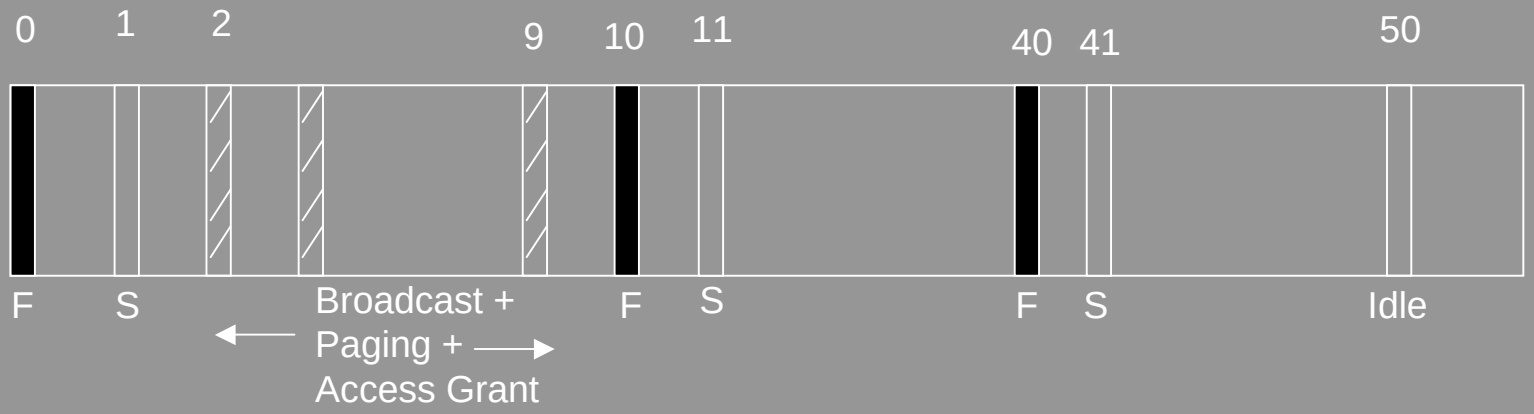
  ⇨ set stealing Flag F to indicate this

Simplex Control Channels: Downlink

- in slot 0 of specific beacon carriers (frequencies stored in SIM)
- 51-multiframe : 51 and 26 are mutually prime!

⇨ slots of 51-multiframe will “file past” **idle slot** of 26-multiframe even when TCH is present

⇨ MS can tune to control slot during idle slots

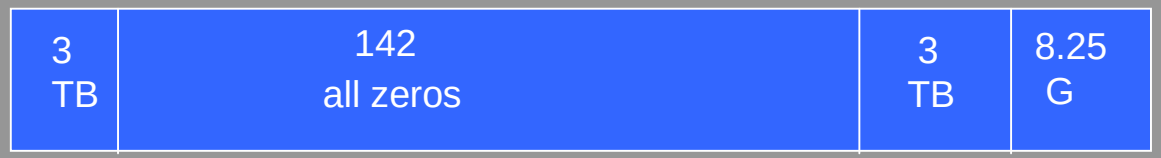


- slot 0 of beacon is transmitted continuously by BTS

⇨ “empty” bursts are filled with dummy data

Frequency Correction Channel (FCH)

- slot 0 in frames 0, 10, ……40 of control multiframe (x 51) are for frequency offset estimation and correction



- all-zero data ⇨ constant frequency
- when MS is turned on, it can hunt continuously for FCH on beacon all carriers in its SIM list

  ⇨ when found, look in slot 0 of next frame for Synchronisation Burst

- One beacon per cell

Synchronisation Channel (SCH)

- first data reception after turning MS on

  ⇨ long training sequence (64 bits)

- 78 bits containing frame number and **BSIC**

  ⇨ can determine slot number (SCH is slot no.1), multiframe, superframe and hyperframe numbers

- BSIC is 6 bit “colour code” for the beacon frequency

  ⇨ adjacent cells will have different “colours” (BSICs)

S burst

Broadcast Paging and Access Grant Channels

- **B**roadcast **CH**annel
  - – used for transmitting IDs of network, BTS (I.e., cell), RACH parameters
- **P**aging **CH**annel
  - – for paging MS during incoming calls
  - – paging channel divided into sub-channels (one out of every ‘n’ PCH slots)

    ⇨ MS wakes up less often in idle mode
- **A**ccess **G**rant **CH**annel
  - – used to grant access after MS sends its ID on RACH
  - – dedicated duplex signalling channel assigned to avoid RACH thereafter for the call

Uplink Simplex Channel: Random **A**ccess **Ch**annel

- time slot 0 (control slot) of beacon on all frames
- shorter than normal burst : 60 guard bits extra

  ⇨ even a burst from distant MS, without timing adjustment for propagation delay, will not overlap into next slot
- first burst from MS to be detected

  ⇨ longer training sequence
- 36 bits for encrypted data
- slotted ALOHA random access protocol
  - parameters obtained from BCCH

Dedicated Signalling Channels

- need these when TCH is not (yet) assigned, or, for user service (like messaging) not requiring TCH
  - like TCH, but of lower capacity
- **S**tandalone **D**edicated **C**ontrol **CH**annel obtained by dividing TCH/F into 8 parts
  - a time slot in four contiguous frames (for 23 bytes message), but a gap of ‘n’ frames before next such occurrence
- SDCCH/8 typically de-allocated if TCH is assigned

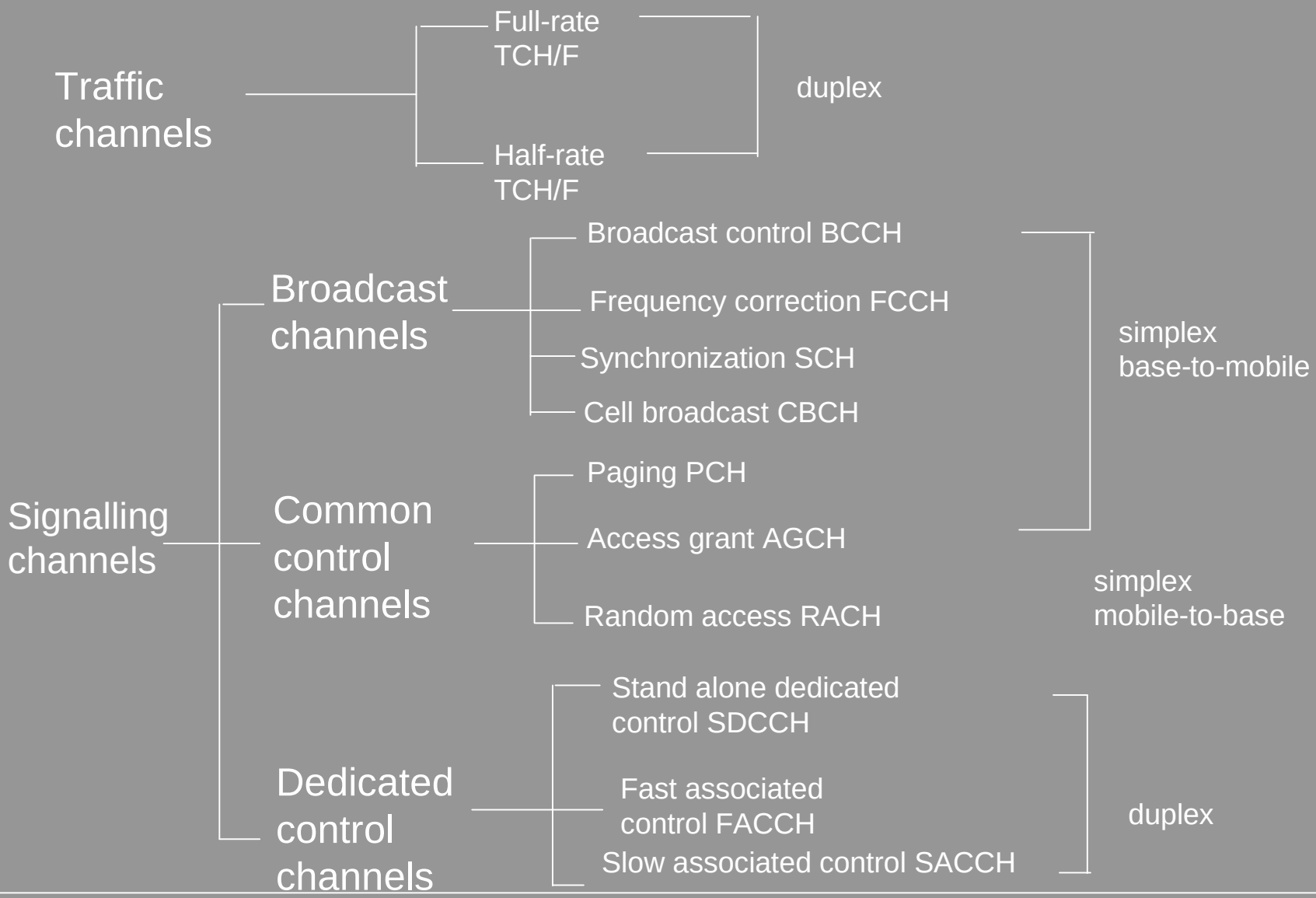
  ⇨ SACCH becomes available

Cell Broadcast Channel

- **CBCH** consists of 4 occurrence of time slot 0 in 4 contiguous frames in eight 51-multiframes (~ 2 secs)

- 80 byte message can be broadcast to all MS once every 2 sec

GSM Logical Channels : Summary



Combining Channels on Carriers

- Half-rate RACH/H, SDCCH/4 possible
- similarly one-third rate PCH/3 and AGCH/3 possible

⇨ allows traffic, common and dedicated control channels on one carrier

Example : small capacity cell with 1 carrier (also the beacon)

slot 0: FCCH, SCH, BCCH, PCH/3, AGCH/3, RACH/H, SDCCH/4

slot 1-7: TCH/F

Example : large capacity cell with 12 carriers (96 slots)

slot 0 of beacon: FCCH, SCH, BCCH, PCH, AGCH, RACH

slot 2,4,6: BCCH, PCH, AGCH (additional)

5 slots : SDCCH/8
87 slots : TCH/F

Timing Advance

- Propagation delay : ~1μs per 300 m
- MS synchronised to BTS clock as received by MS ***d*** meters away

  ⇨***d*** / 300 μs offset
- Transmission from MS in slot ***n*** received by BTS ***d*** / 150 μs late

  ⇨can exceed guard time of 8.25 bit durations (8 x 3.7 μs)
- BTS measures delay in reception on RACH
  - 68.5 guard bits available in RACH (~250 μsec)
- BTS informs MS on SACCH about a delay value 0-233 μsec ≡ 0-35 km
  - sent as number of bit periods n [0 - 63] ≡ requires 6 bits to code

Location Area

- should a paging message go on PCH channels of all BTSs?

  ⇒ heavy load on PCH

- can reduce load if MN knows approximate location of MS

  ⇒ concept of **L**ocation **A**rea (**LA**)

- LA is a group of cells

  – all cells must belong to same MSC

- MS listers to LA ID from BCCH

  ⇒ MS (i.e., SIM) registers itself in the LA with MSC

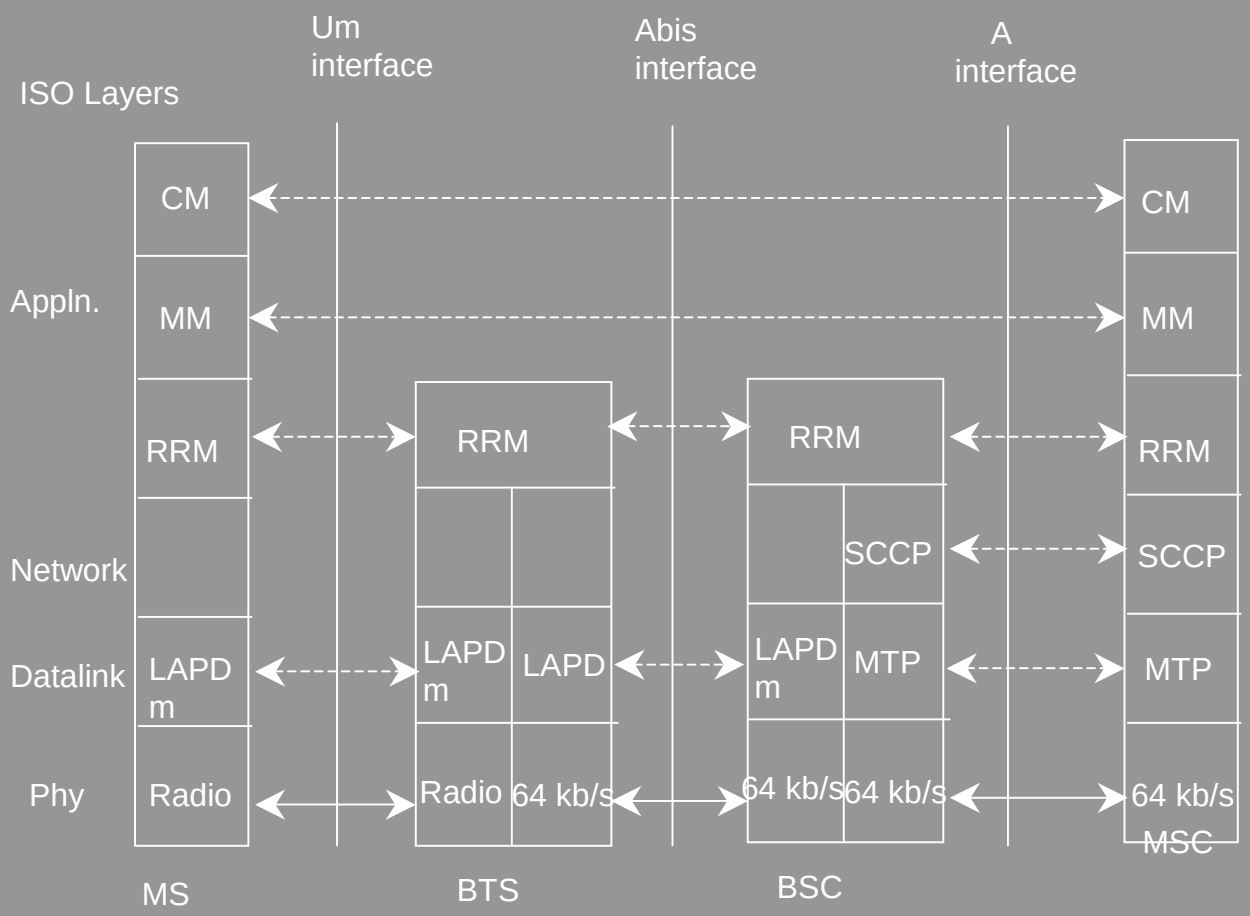
- LA updation also helps MSC determine if call restrictions apply ; e.g., in case of roaming

Locking to a BTS (i.e., Cell)

- search beacon frequency (ies) for FCH, SCH and BCCH
  - list of beacons for a LA stored in SIM (from previous locked state)
  - search all frequencies if in new LA when MS is tuned ON
- periodically lock to beacons of neighbouring cells also, i.e., listen to FCH, SCH, BCCH
  - estimate cell quality parameter
  - based on received power level,and some parameters on BCCH related to max Tx power of BTS, etc
- if better cell found in same LA, lock to new cell
- if ***sufficiently better*** (with “handicap”) cell found in another LA, lock to it

  $\Rightarrow$ perform LA update

GSM Signalling Protocol Layers



CM: call management

MM: mobility management

RRM: radio resource management

SCCP: signal connection control part (SS7)

MTP: message transfer part (SS7)

LAPD: link access protocol -D channel (ISDN)

LAPDm: modified LAPD (GSM)

Data Link Layer Protocols

- All protocols are HDLC - like
- LAPD : as in ISDN D-channel link layer
  - 260 byte payload
- LAPm : GSM physical layer provides framing

  ⇨ no need for framing, bit stuffing, etc.
  - 23 byte packets
- MTP : as in SS7
  - 272 byte payload

Signalling

- MS-BSC: radio resource management
  - channel assignment, timing advance, power control, handover (MS-BTS only for handover)
- MS-MSC: call management
- BSC-MSC: handover co-ordination
- MSC-HLR + Auc: interrogation of MS location, authentication
- MS-VLR: LA update

Circuit-Switched User Data

- for user data between **T**erminal **A**dapter of MS and **I**nter **W**orking **U**nit of MSC
- **R**adio **L**ink **P**rotocol provides for ARQ between TA and IWU
- uses the framing provided by GSM physical layer to reduce overhead
- frame size is 240 hits
  - 200 bits of user data

Radio Resource Management

- paging, access request and access grant
  - access always initiated by MS
- allocation and teardown of dedicated signalling and traffic channels
  - dynamic re-configuration of channel pool
- handover management
  - channel quality and adjacent cell measurements by MS
  - co-ordination with MSC
- ciphering/encryption control
  - access initiation always in clear mode

    transition to encrypted mode occurs later
- orchestrated by BSC

  ⇨
  - MSC involved only in handover, due to traffic considerations

Handover Management

- handovers can be due to
  - movement out of cell, i.e., *rescue*, even call break and re-establishment can occur
  - reduction of interference , i.e., *confinement*, or good civic behaviour
  - *traffic* congestion in a cell
- ***downlink*** measurements by MS on neighbouring cell beacons reported to BSC
  - reports made 1-2 times per second
- BTS makes measurement of MS ***uplink*** transmission
- MSC + BSC decide handover based on measurements and traffic levels
  - cells involved may be managed by same BSC, different BSCs, even different MSCs.
- MS ***pre-synchronised*** to neighbouring cells by listening to their SCH
- MS sent handover command with BSIC channel ID, and other parameters (power level, etc)

Mobility Management

- Location area updation and paging control
- HLR contains user registration information
- VLR knows LA of each MS
  - VLR obtains subscriber information from HLR
- incoming call to MS always involve a query to HLR
- **I**nternational **M**obile **S**ubscriber **I**dentity: a world-wide unique ID r
  - MS roaming into new GSM MN provides IMSI to visited MSC/VLR

    ⇨ query sent to home HLR (whose SS7 address is known, given IMSI)
- Authentication and Encryption involve keys stored in SIM
  - new key computed each time and stored
  - Temporary **MSI** assigned by VLR in lieu of IMSI

    ⇨ minimises transmission of IMSI in clear mode

Call Management

- manages call establishment and teardown
  - treats MS-MSC (visited) link as fixed link
- Gateway MSC (**GMSC**) plays central role for incoming calls to GSM MN
- GSM subscriber's directory number part of country's PSTN numbering plan
  - country code+STD code+subscriber number

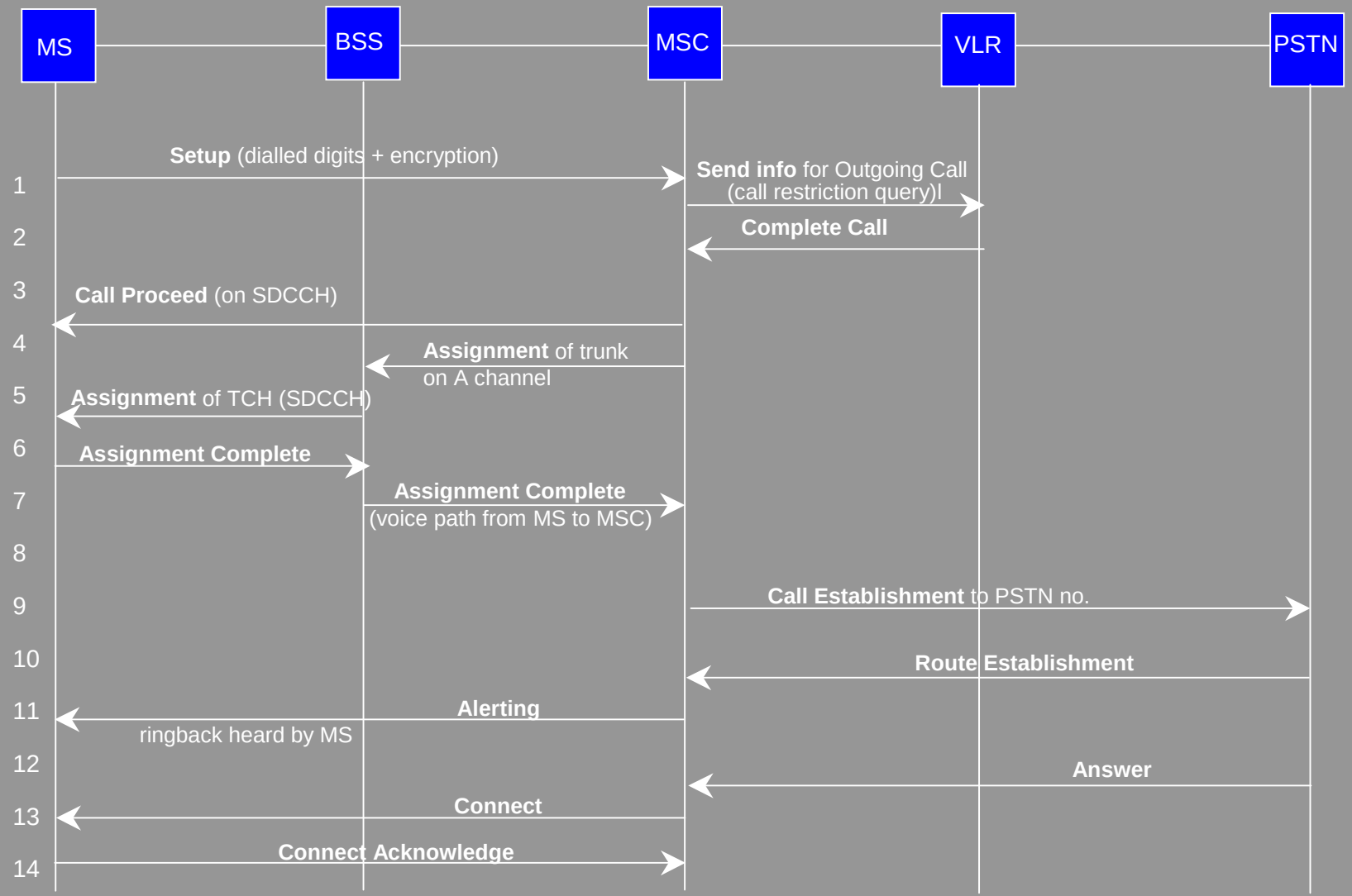
    ⇨ gives SS7 address of GMSC (where HLR is present)
- HLR maps directory number to IMSI and sends query to VLR where MS is registered

  ⇨ VLR sends routing information of visited MSC
- GMSC establishes incoming call to visited MSC

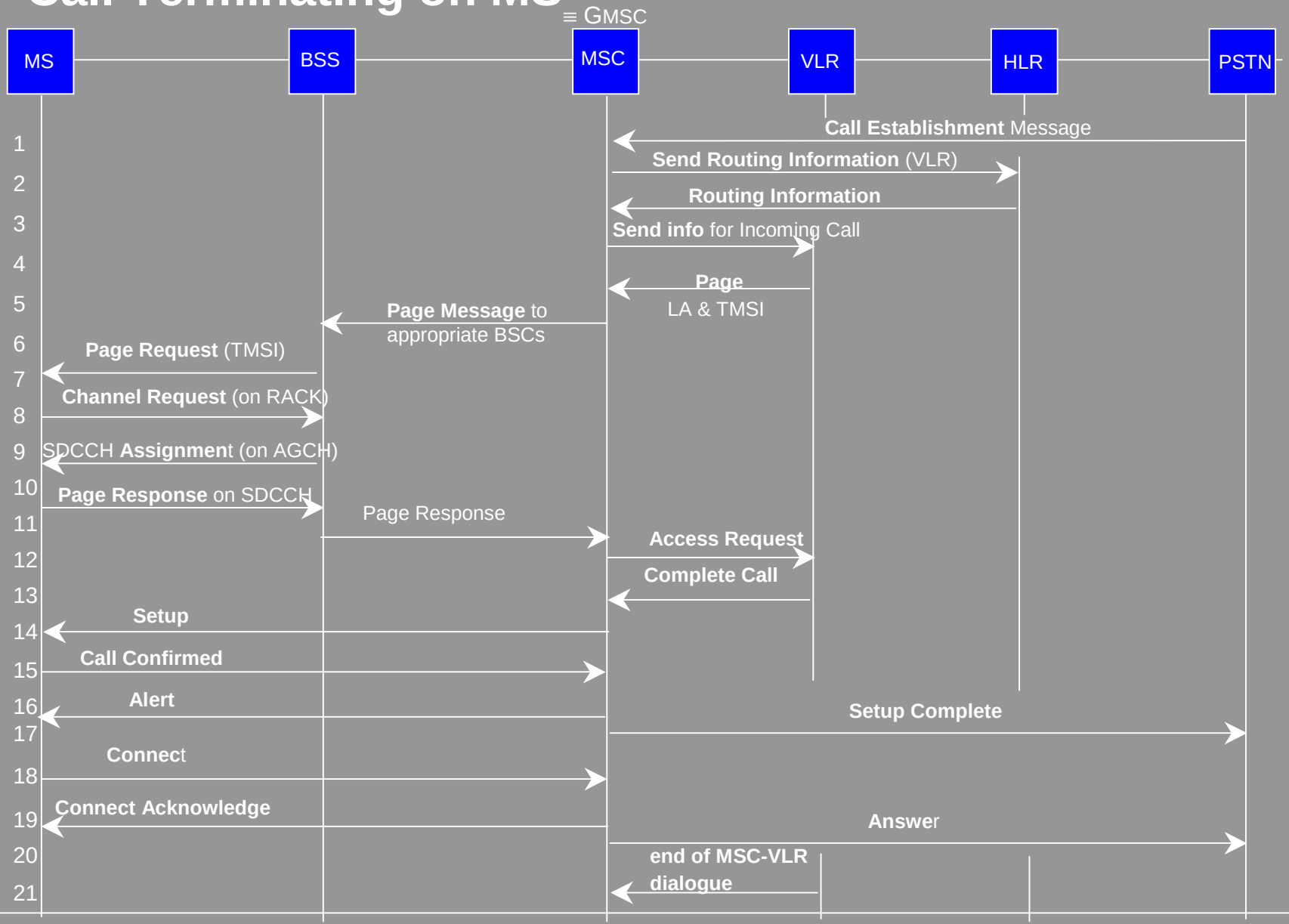
  ⇨ caller pays till GMSC

  ⇨ GSM subscriber pays for call from GMSC to MS
  - could involve a terrestrial link through PSTN

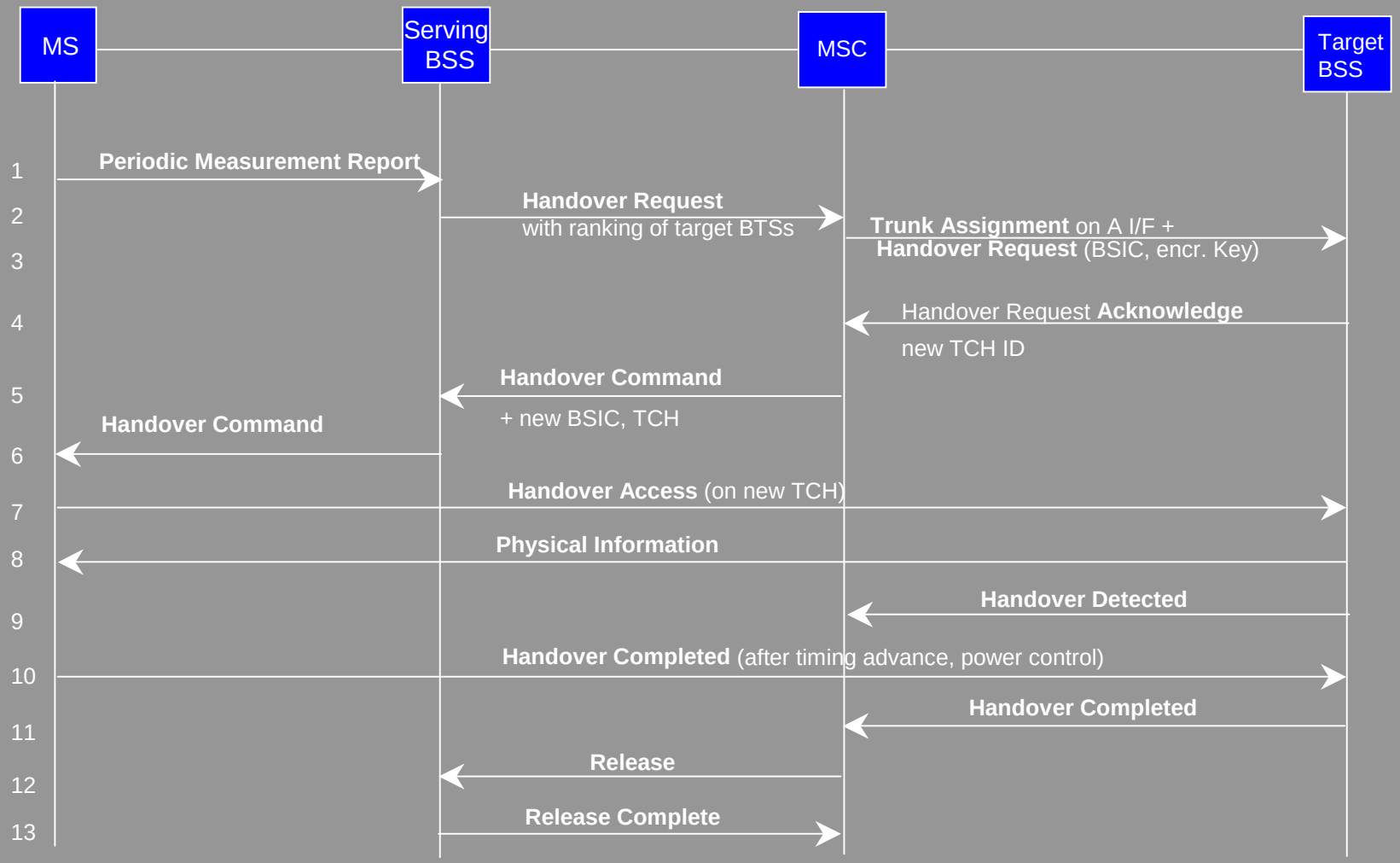
Call Setup by a MS



Call Terminating on MS



Intra - MSC Handover



GSM 2G Services

- circuit-switched services
  - voice: full rate (13 kbps) and half-rate (5.6 kbps)
  - data: fax, modem, X.25…..

    ⇨ terminal adapter needed at MS, modem/fax/PAD needed at MSC
  - supplementary services common in PSTN (CLIP, call barring, call waiting,…….)

- short messages
  - broadcast messages on CBCH
  - 2-way paging on SACCH or SDCCH using **S**hort **M**essage **T**ransport **P**rotocol between MS and SMC-Service Centre at MSC

References

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2. *Principles and Applications of GSM*, V. K. Garg and J. E. Wilkes, Prentica-Hall, N. J., 1999

3. *Wireless Communications: Principles and Practice*, T. S. Rappaport, Prentica-Hall, N. J., 1996