King Fahd University of Petroleum & Minerals
Computer Engineering Dept

COE 543 – Mobile and Wireless Networks

Term 022

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Lecture Contents

1.

Global System for Mobile (GSM)

- ETSI standard for 2nd G pan European digital cellular with international roaming
- Bands 890-915 and 935-960 MHz - PLMN

GSM Services – Phase 1

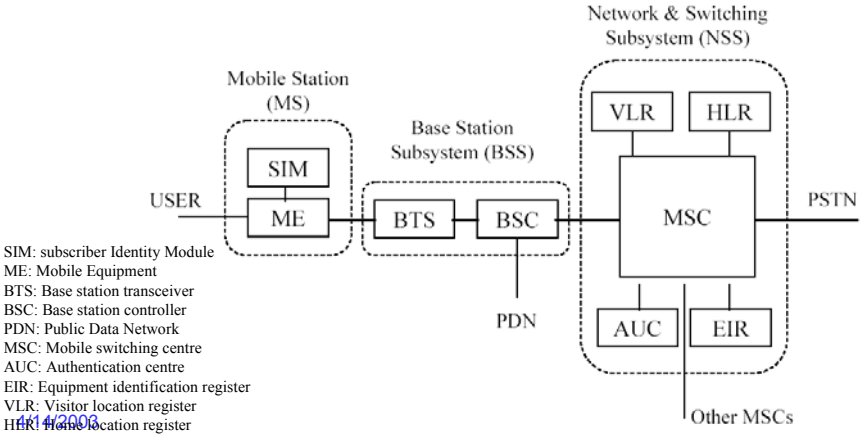
- Teleservices: Telephony, SMS, Videotext access, Telex, FAX, etc.
  - Full-rate voice @ 13 kb/s
  - SMS unicast or multicast
- Bearer Services: Asynchronous data (0.3-9.6 kb/s), Synchronous data (2.4-9.6 kb/s), Synchronous Packet Data, etc.
  - The lower layers and frame format of the standard should specify how these transmissions would be implemented over the air-interface
- Supplementary Services: Call Forwarding, Call Barring

GSM Services – Phase 2

- Teleservices: optional implementation
  - Half-rate speech coder
  - Enhanced full-rate
- Supplementary Services:
  - Calling line identification,
  - Connected line identification,
  - Call waiting,
  - Call hold,
  - Etc.

Reference Architecture of GSM

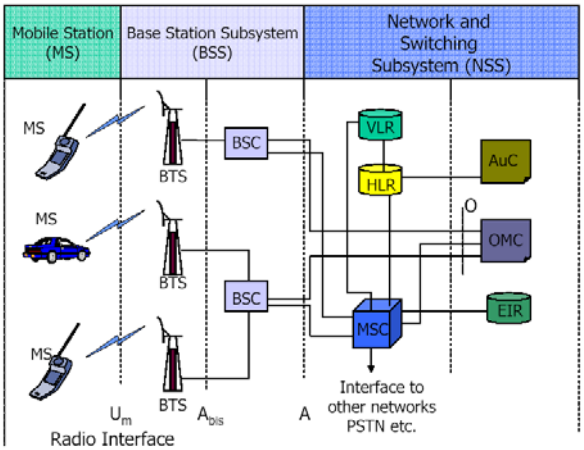
- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network and Switching Subsystem (NSS)



SIM: subscriber Identity Module
ME: Mobile Equipment
BTS: Base station transceiver
BSC: Base station controller
PDN: Public Data Network
MSC: Mobile switching centre
AUC: Authentication centre
EIR: Equipment identification register
VLR: Visitor location register
HLR: Home location register

Reference Architecture of GSM – cont'd

- Um: Air (User) Interface
- Abis:
- A:



Mobile Station (MS)

- Um: MS ←→ BSS
- Two Elements:
  - ME: the actual phone hardware
  - SIM: smart card – specifying user and type of services – 4 digit pin number
    - Avoid roaming charges by buying local SIMs
    - Multiple SIMs and one ME
- ISDN phone number
- International Mobile Subscriber Identity (IMSI)
  - different than phone number
  - Used for internal networking applications
  - Part of the SIM

Base Station Subsystem (BBS)

- Access point to the wired network!
- Speech codec
  - Backbone 64 kb/s PCM digitized voice → 13 kb/s digitized voice
  - 13 kb/s digitized voice → backbone 64 kb/s PCM
- Signaling:
  - Packets exchanged with infrastructure to perform call setup, reserve resources, etc.
- Connects to PSTN and PDN

Base Station Subsystem (BBS) – cont'd

- BTS: transmitter – receiver
  - Physical communication
  - Physically located in the centre of the cell
  - Several hundred BTSs may belong to the same BBS
- BSC: an advanced switch – with RRM responsibilities
  - Frequency administration
  - Handover among BTSs inside a BBS
  - Usually co-located with the MSC

Network and Switching Subsystem

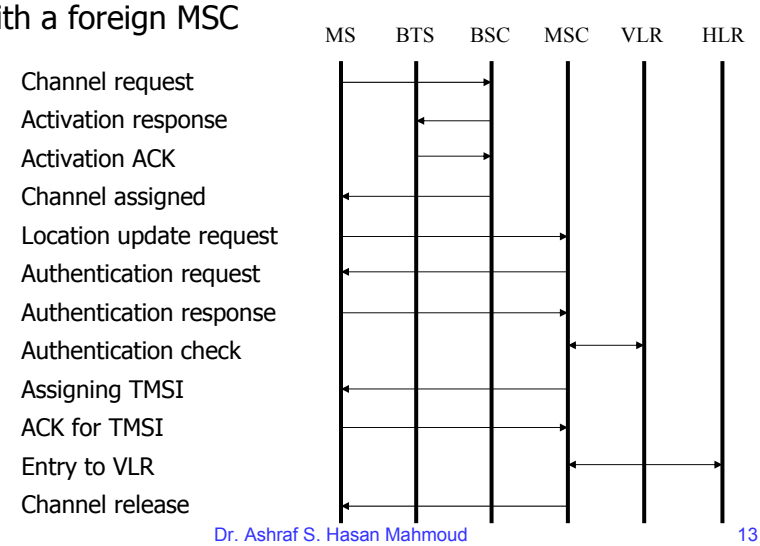
- Responsible for network operations
  - Connection to other wired and wireless networks
  - Support registration and maintenance of connection with MS
- Connects to the rest of PSTN using ISDN
- Components:
  - MSC – Hardware
  - HLR, VLR, AUC, EIR – Software
- MSC – talks SS7 with other MSCs or the PTSN
- Gateway MSC –
  - The specific MSC which is connected to the PSTN
  - Status info regarding mobility

Network and Switching Subsystem – cont'd

- HLR: software database to manage mobile subscriber account: address, service type, current location, forwarding address, authentication/ciphering keys, billing info, etc.
- VLR: temporary software database similar to the HLR identifying the subscribers visiting inside the coverage area of MSC
  - Assigns temporary TMSI (to avoid using IMSI over the air)
  - Essential for implementation of call routing and dialing in a roaming situation
- AUC: provides authentication and encryption of subscribers
  - Different classes of SIMs have their own algorithms – NSS should operate with all
- EIR: software database to manage identification of MEs
  - IMEI – to report stolen equipment, etc
  - Optional implementation

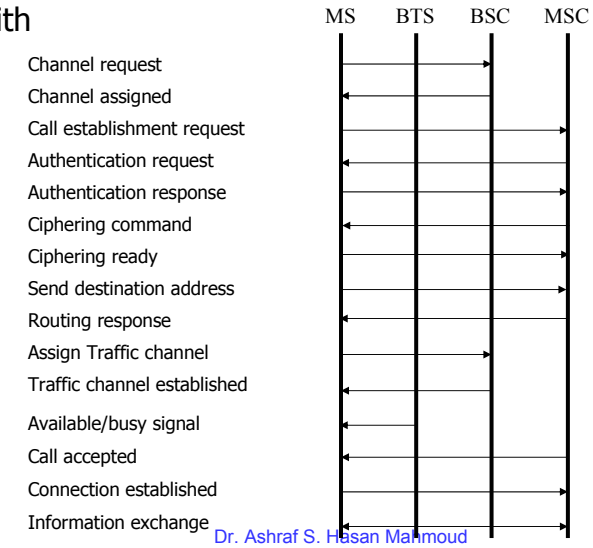
Registration

- With a foreign MSC



Call Establishment

- With

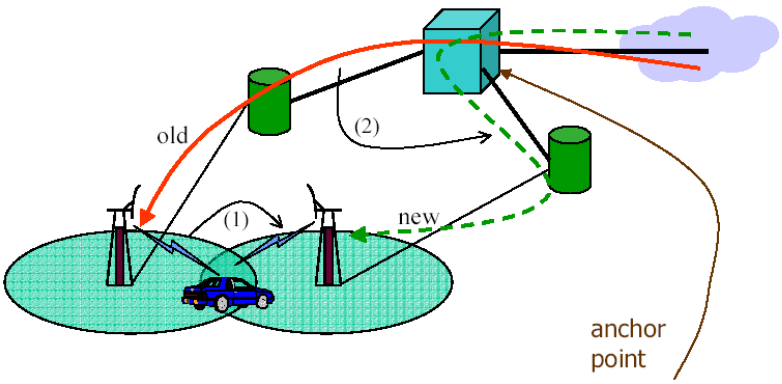


Handoff - General

- MS is usually "connected" to a home BTS (point of attachment)
  - Receive voice/data calls
- When MS moves to the service region of another attachment point – it executes handoff
- Hard handoff – break before make
- Seamless handoff – make before break
  - Softhandoff
- Handoff control:
  - Network – voice networks – AMPS - Network controlled Handoff (NCHO)
  - Mobile terminal – - IEEE802.11 - mobile data and WLANs – Mobile Controller Handoffs (MCHO)
  - Mobile + network – GPRS – Mobile Assisted Handoff (MAHO)

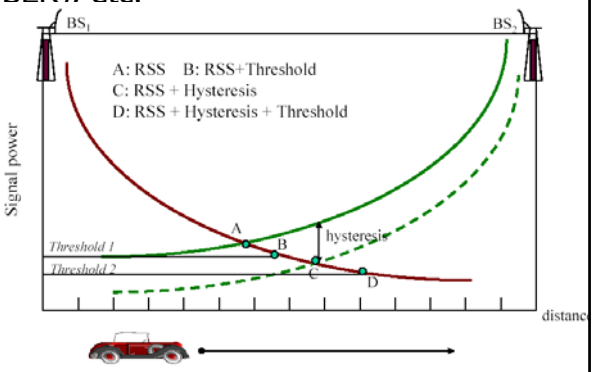
Handoff – General (2)

1. Handoff management process: Is handoff needed now?
2. Restructure connection



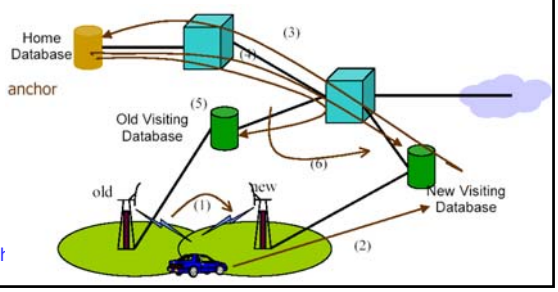
Handoff – General (3)

- Metrics: received signal strength (RSS), carrier-to-interference ratio (CIR), signal-to-interference ratio (SIR), bit error rate (BER), block error rate (BLER), symbol error rate (SER), etc.
  - To avoid the ping-pong effect: hysteresis margin, dwell timers, and averaging windows



Handoff – General (4)

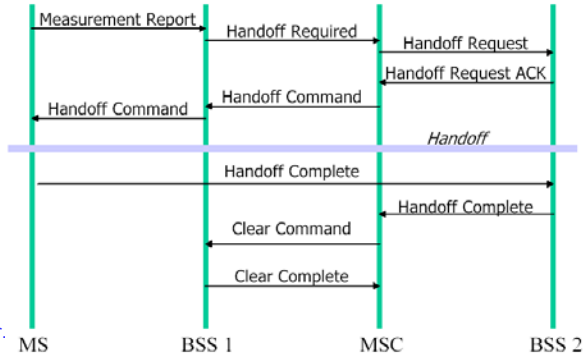
1. Decision is made to handoff – initiated
2. MS registers with new visiting database via handoff announcement msg
3. VLR sends request to HLR to obtain profile and authenticate MS
4. HLR responds with MS profile and authentication
   - VLR may reserve (ahead of time) channels for new connection if voice
5. HLR sends msg to old VLR to flush MS info
   - Data packets intended for MS at old VLR are also flushed or routed to new VLR
6. Old VLR flushes info pertaining to the MS or routes its packets to new VLR



Handoff - GSM

- BTS provides MS with list of available channels in the neighboring cells via BCCH
- MS monitors RSS from the BCCHs of those neighbors
- MS reports values to the MSC using SACCH (MAHO procedure)
- BTS monitors the RSS from MS to decide when to initiate handoff

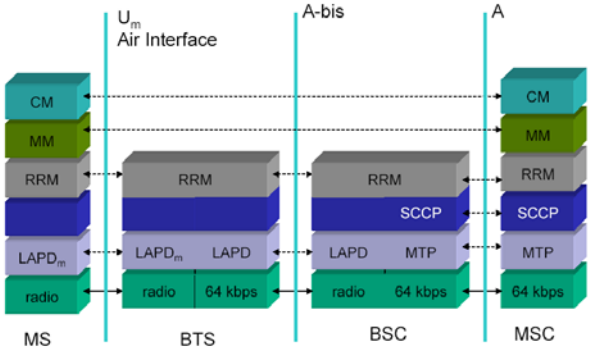
- For handoff
  - MSC negotiates a new channel with new BSS
  - MSC indicate to the MS
  - MS starts handoff exchange with new BTS



GSM Protocol Structure

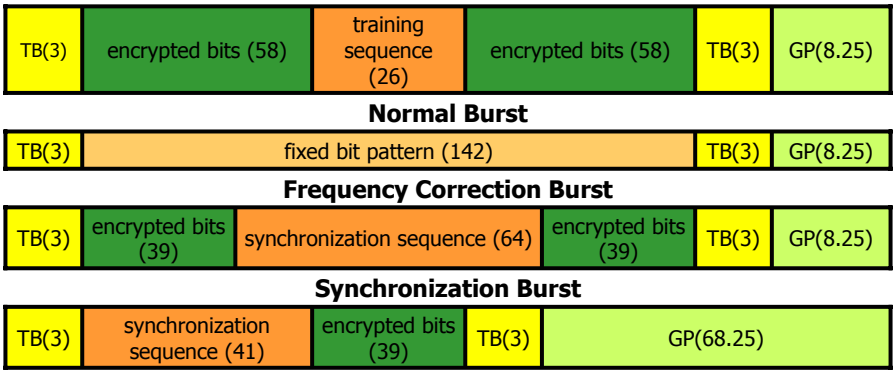
- Um – air-interface
- Abis and A - ~ ISDN
- Abis – supports voice at 64 kb/s and data/signaling at 16 kb/s
  - LAPD is the DLL for ISDN
- A-interface: 2 Mb/s CCITT using SS-7
  - MTP and SCCP – provide error free transport and logical connection

- MTP – Message transport part
- SCCP – Signaling connection control part
- MM – Mobility management
- CM: connection management
- RRM: radio resource management
- LAPD: Link access protocol -D



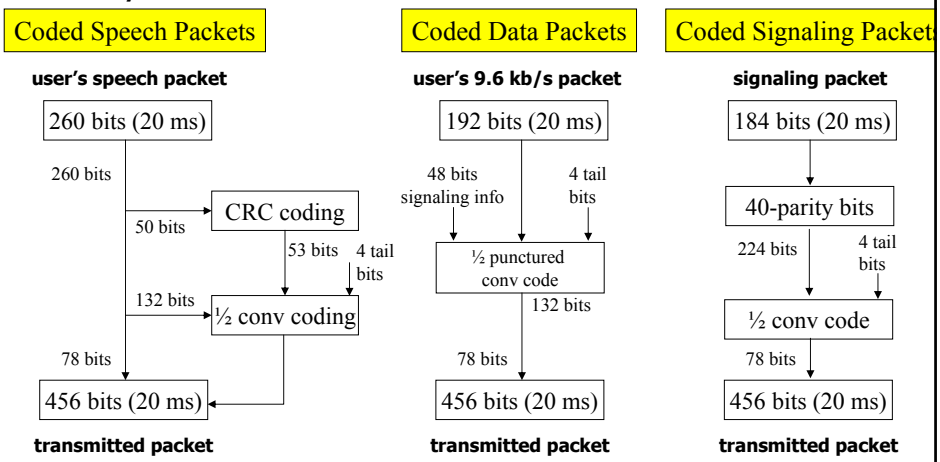
GSM – Physical Layer

- 124-200 kHz carriers
- Four burst types



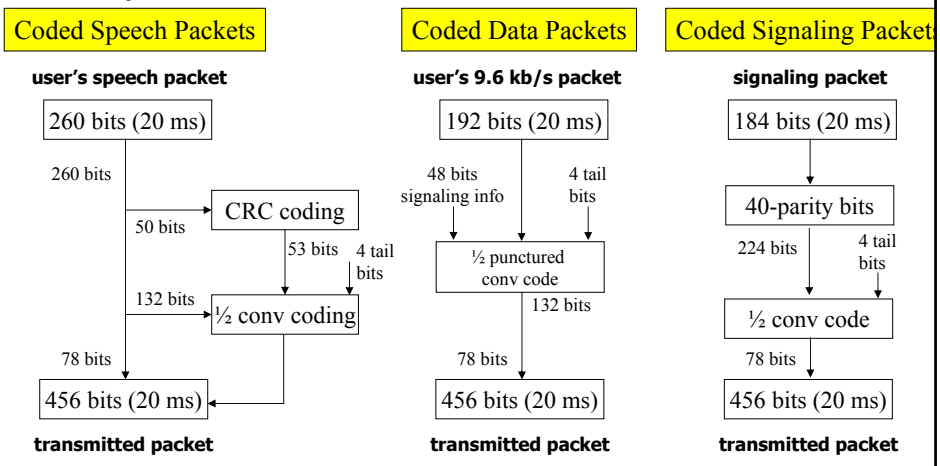
GSM – Payloads

- Payloads



GSM – TDMA Frame Hierarchy

- Payloads



Slides by: *Professor David Everitt*

GSM Channel Structure

Channel Requirements

- **Traffic Channels**
- **Associated Signalling Channels**
  - Call-related signalling
- **Common Signalling Channels**
  - Cell information channel(s) (downlink)
  - Paging channel (downlink)
  - Access channel(uplink)

These channels all need to be efficiently multiplexed into the GSM frame structure

Traffic Channels

The GSM channel structure includes three types of physical channel, called traffic channels (TCH):

- **TCH/F** Full rate traffic channel (13 kbps speech channel)
- **TCH/H** Half rate traffic channel (7 kbps speech channel)
- **TCH/8** One-eighth rate traffic channel (used for low-rate signalling channels, data channels, common channels)

Associated Signalling Channels

- **SACCH** (slow associated control channel)
  - Used for call-associated signalling, particularly measurement data needed for handover decisions
  - A TCH is always allocated with an associated SACCH
  - The TCH plus SACCH combination is designated TACH
- **FACCH** (fast associated control channel).
  - This indicates call establishment progress, authenticates subscribers, and commands handovers, etc
  - Makes use of a TCH
  - A "stealing flag" on the TCH indicates whether it is being used for signalling, or for call transmission

Associated Signalling Channels cont'd….

- **SDCCH** (stand alone dedicated control channel).
  This uses a TCH/8 channel, and is used solely for passing signalling information (e.g. location updating), and not for calls.

Common Signalling Channels

Downlink channels (base station to mobile):

- **FCCH** (frequency correction channel) is used to identify a beacon frequency
- **SCH** (synchronisation channel) follows each FCCH to obtain synchronisation
- **BCCH** (broadcast control channel) is broadcast regularly and received by each mobile station while it is in the idle mode. It gives information about the cell, such as which network the cell belongs to.
- **PAGCH** (paging and access grant channel) is used to page a called mobile, and to allocate a channel during call set-up. There may be a full rate PAGCH/F or a one-third rate PAGCH/T.

…cont'd next page

Common Signalling Channels cont'd...

Downlink channels (base station to mobile) cont'd...

- **CBCH** (cell broadcast channel) can be used to transmit one 80 octet message every 2 seconds. It uses half a TCH/8 channel.

How cell selection works:

The MS finds the FCCH burst, then looks for an SCH burst on the same frequency to obtain frame synchronisation. The MS then receives BCCH on several time slots and selects a proper cell.

Common Signalling Channels cont'd...

Uplink channels (mobile station to base station):

There is only one common access channel on the uplink

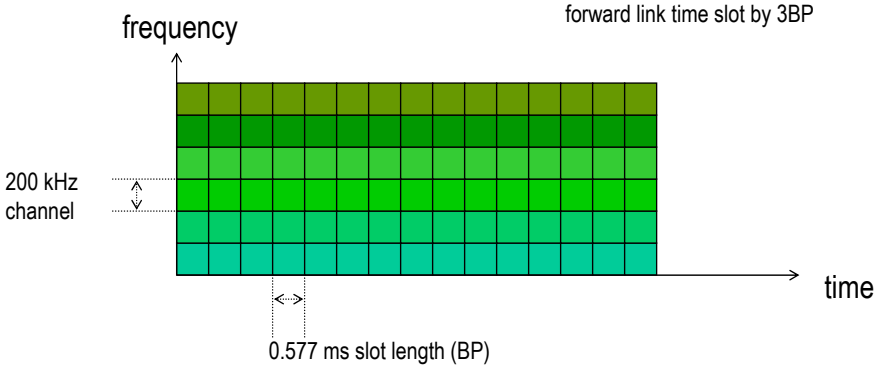
- **RACH** (random-access channel).

The MS uses this channel to access the network. These may be provided as a full rate RACH/F or a half rate RACH/H.

Multiple Access Scheme

Slot length is called a burst period, or BP, and is of length 15/26 ms = 0.577 ms.

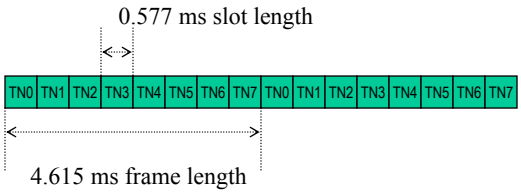
Forward link and reverse link relations:
Frequencies separated by
–45 Mz for 900 MHz band
–75 MHz for 1800 MHz band
Reverse link time slot follows forward link time slot by 3BP



Multiple Access Scheme cont'd...

Traffic channels and signalling channels need to be *efficiently* multiplexed into this slot structure (non-trivial !)

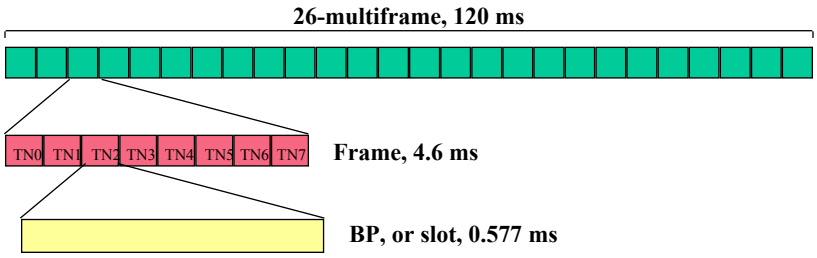
A full-rate traffic channel TCH/F consists of one slot every 8 BP
=> frame length is 8 BP = 4.615 ms.



Slots within a frame are numbered TN0, TN1,…,TN7

Multiple Access Scheme cont'd...

Traffic channel frames are transmitted in groups of 26,
known as a "26-multiframe", of length 120 ms (= 8 × 0.577 × 26 ms)



Multiple Access Scheme cont'd...

The 26-multiframe structure allows the efficient mutiplexing of the associated signalling channels.
The TCH/F is always allocated with its associated SACCH as follows:

- A "26-multiframe" of 26 × 8 BP is transmitted
- A single **TCH/F** uses one BP in 24 of the 26 frames of the 26-multiframe
- The associated **SACCH** uses one BP per 26-multiframe
- One slot in the multiframe is left idle (assists handover measurements)
- Therefore, a single **TCH/F** plus **SACCH** combination uses one BP per frame (26 BP total per 26-multiframe)

Note: SACCH associated with a TCH/F consists of 1 slot every 120 ms.

Common Signalling Channels

Common channels are based on a cycle of 51 frames,
i.e. a "51-multiframe", of length 235 ms

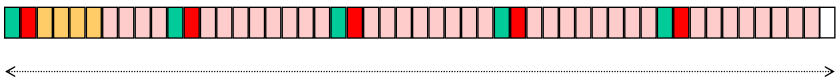
Why 51?

- Deliberately different from the 26 used for traffic channels
- To allow MS to listen to SCH and FCCH of surrounding BSs, as needed for handoff

Common Signalling Channels

Downlink:

- The FCCH and SCH between them use 10 slots per cycle of 51 frames.
  - FCCH uses every 10th slot in a cycle (a slot in frames 0, 10, 20, 30 40)
  - SCH uses a slot one frame after each FCCH slot (a slot in frames 1,11,21,31,41)
- The BCCH and PAGCH/F together use 40 slots per 51 multiframe;
  - BCCH in frames 2,3,4,5 and
  - PAGCH/F in frames 6-9,12-19, 22-29, 32-39, 42-49



51-multiframe, one slot per frame shown

Common Signalling Channels

Uplink:

- A RACH/F uses one slot every frame

Uplink:

RACH/F: one slot per frame

51-multiframe, one slot per frame shown

Fractional Rate Channels

- **Traffic Channels:** The half-rate traffic channel TCH/H and one-eighth rate traffic channel TCH/8 use similar ideas to TCH/F, but are slightly more complex. They are both always allocated with an associated SACCH.
- **Forward Link Common Signalling Channels:** The BCCH and one-third rate paging channel PAGCH/T together use 16 slots per 51 multiframe:
  - BCCH in frames 2,3,4,5 and PAGCH/F in frames 6-9,12-19
- **Reverse Link Common Signalling Channels:** A half-rate random access channel RACH/H uses 27 slots in the cycle
  - a slot in frames 4,5,14-36, 45,46
    (allows grouping with 4 TACH/8, i.e. 4 (TCH/8 plus its SACCH))

Channel Organisation in a Cell

Several of the signalling/control channels can be grouped together so that they make use of one slot per frame. For example, one slot per frame could be used for:

- 1 (TCH/F plus associated SACCH)
- 2 (TCH/H plus associated SACCH)
- 8 (TCH/8 plus associated SACCH)

Traffic Channel Combinations

- (1 SCH + 1 FCCH + 1 BCCH + 1 PAGCH/F) on the downlink
  + 1 RACH/F on the uplink
- (1 BCCH + 1 PAGCH/F) on the downlink
  + 1 RACH/F on the uplink

Signalling Channel Combinations

- 1 BCCH + 1 PAGCH/T on the downlink
  + 1 RACH/H on the uplink
  + 4 (TCH/8 plus associated SACCH) using both uplink and downlink.

Both Traffic and Signalling

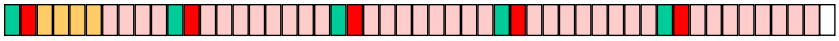
etc

Example Channel Organisation in a Cell

For example, a combination of
1 SCH + 1 FCCH + 1 BCCH + 1 PAGCH/F on the downlink uses (per 51 multiframe):

Downlink:

- FCCH: slot in frames 0, 10, 20, 30, 40
- SCH: slot in frames 1, 11, 21, 31 41
- BCCH: slot in frames 2, 3, 4, 5
- PAGCH/F: slot in frames 6-9, 12-19, 22-29, 32-39, 42-49



Uplink:

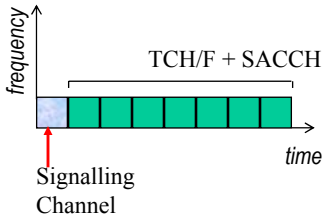
- RACH/F: one slot per frame

Example: Small Capacity Cell

One TRX, consisting of:

TN 0: FCCH, SCH, BCCH, PAGCH/T, RACH/H,
4 (TCH/8 plus associated SACCH)

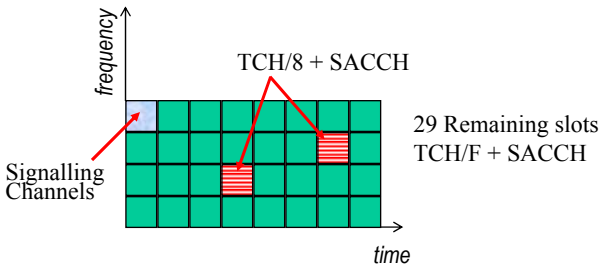
TN 1 to 7: 1 (TCH/F plus associated SACCH)



Example: Medium Capacity Cell

Four TRXs, consisting of:

One TN 0 group: FCCH, SCH, BCCH, PAGCH/F, RACH/F
Two sets of 8 (TCH/8 plus associated SACCH)
29 (TCH/F plus associated SACCH)



Example: Large Capacity Cell

Twelve TRXs, consisting of:

One TN 0 group: FCCH, SCH, BCCH, PAGCH/F, RACH/F

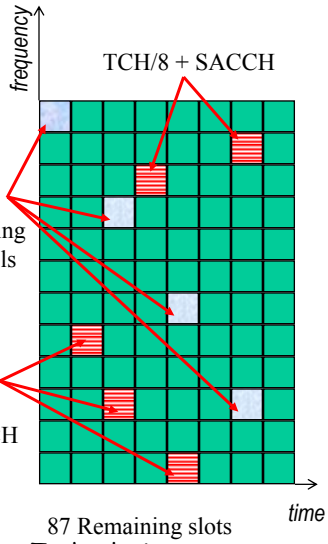
One TN 2 group: BCCH, PAGCH/F, RACH/F

One TN 4 group: BCCH, PAGCH/F, RACH/F

One TN 6 group: BCCH, PAGCH/F, RACH/F

Five sets of 8 (TCH/8 plus associated SACCH)

87 (TCH/F plus associated SACCH)



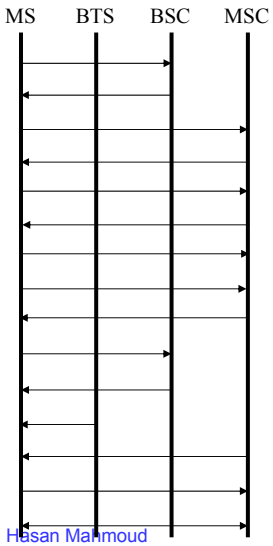
Summary of GSM Frames

- Frame = 8 BP = 4.615 ms
- 26 multiframe = 26 × 8 BP = 120 ms
  - multiplexes traffic channels plus their associated control channels
- 51 multiframe = 51 × 8 BP = 235.4 ms
  - multiplexes the common control channels
- Superframe = 26 × 51 × 8 BP =6.12 s
  - smallest cycle for which channel organisation is repeated
- Hyperframe = 2048 superframes
  - numbering period

Call Establishment – with Logical Channels

- With

1. Channel request (RAACH)
2. Channel assigned (AGCH)
3. Call establishment request (SDCCH)
4. Authentication request (SDCCH)
5. Authentication response (SDCCH)
6. Ciphering command (SDCCH)
7. Ciphering ready (SDCCH)
8. Send destination address (SDCCH)
9. Routing response (SDCCH)
10. Assign Traffic channel (SDCCH)
11. Traffic channel established (FACCH)
12. Available/busy signal (FACCH)
13. Call accepted (FACCH)
14. Connection established (FACCH)
15. Information exchange (TCH)



Example: SMS Service

- DLL defines two service access points (SAPs):
  - Signaling and SMS
- Other data services in GSM are carried over traffic channels
- DLL multiplexes SMS data into signaling info
  - SMS passed as a signaling packet to user