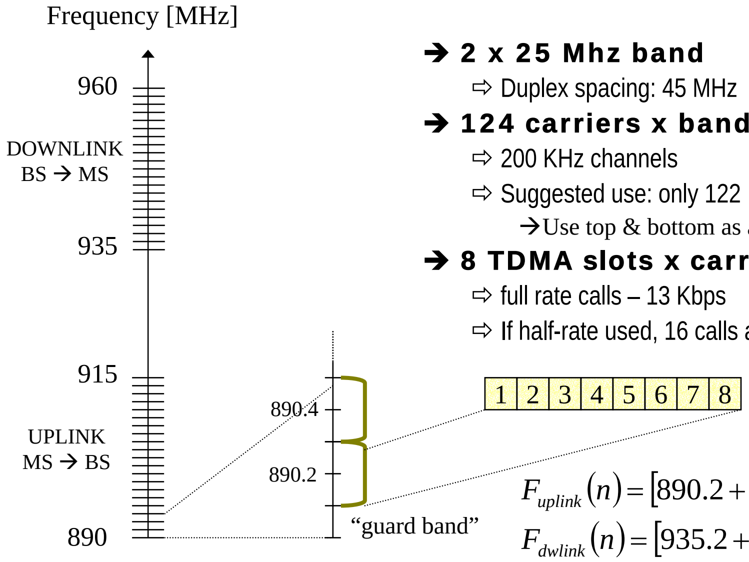
PART 4
GSM – Radio Interface

Lecture 4.1
Physical channels

GSM Radio Spectrum



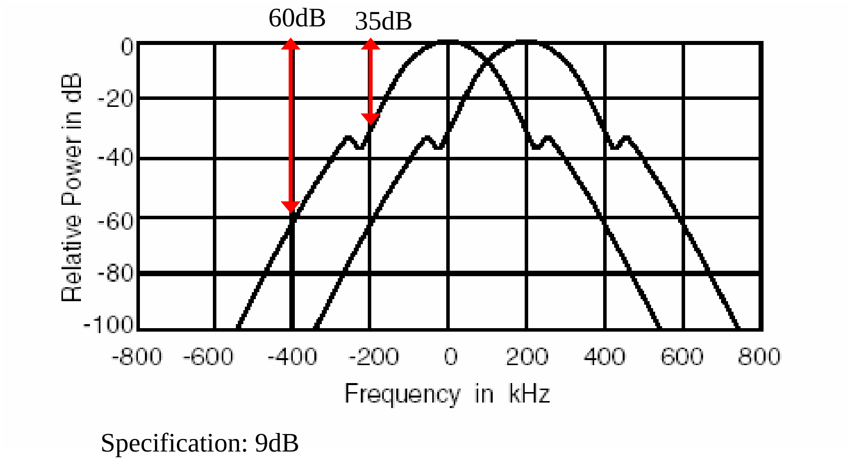
- ➔ **2 x 25 Mhz band**
  - ⇨ Duplex spacing: 45 MHz
- ➔ **124 carriers x band**
  - ⇨ 200 KHz channels
  - ⇨ Suggested use: only 122
    - →Use top & bottom as additional guard
- ➔ **8 TDMA slots x carrier**
  - ⇨ full rate calls – 13 Kbps
  - ⇨ If half-rate used, 16 calls at 6.5 kbps

$$F_{uplink}(n) = [890.2 + 0.2(n-1)]\,\text{MHz}$$

$$F_{dwlink}(n) = [935.2 + 0.2(n-1)]\,\text{MHz}$$

Adjacent channels

(due to GMSK)

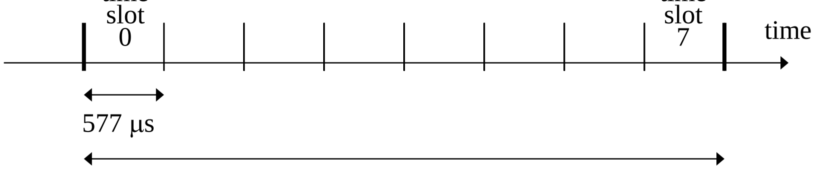


Specification: 9dB

In practice, due to power control and shadowing, adjacent channels Cannot be used within the same cell…

Physical channel

- ➔ **200 KHz bandwidth + GMSK modulation**
  - ➪ 1625/6 kbps gross channel rate (270.8333 kbps)
- ➔ **1 time slot = 625/4 bits**
  - ➪ 156.25 bits
  - ➪ 15/26 ms = 576.9 µs

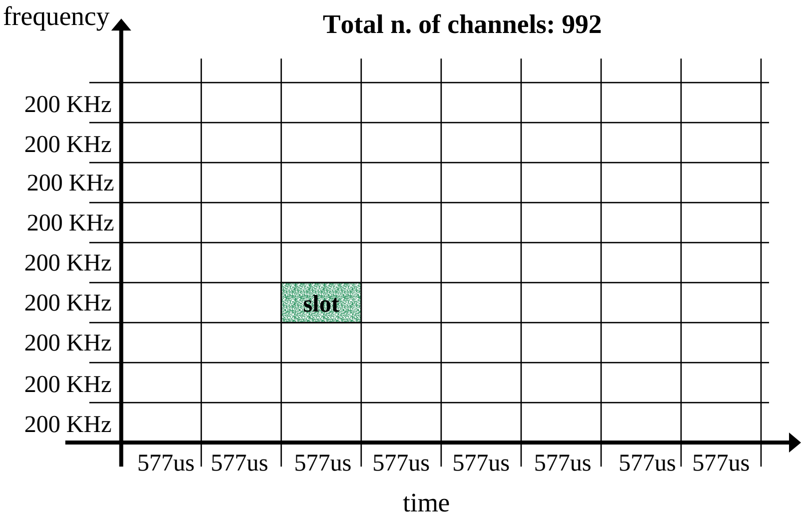


1 frame = 60/13 ms = 4.615 ms

26 frames = 120 ms (*this is the key number*)

Hybrid FDMA-TDMA

physical channel = (time slot, frequency)



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DCS 1800 radio spectrum

- ➔ **Greater bandwidth available**
  - ⇨ EUROPE: 75 MHz band
    - →1710-1785 MHz uplink; 1805-1880 MHz downlink
  - ⇨ ITALY: 45 MHz band from 2005
    - →1740-1785 MHz uplink; 1835-1880 MHz downlink
- ➔ **Same GSM specification**
  - ⇨ 200 KHz carriers
    - →A total of 374 carriers (versus124 in GSM)
- ➔ **DCS 1800 operators**
  - ⇨ Common rule in most of the countries:
    - →First and second operators @ 900 MHz; Third etc @1800 MHz
    - →DCS 1800 deployment (1996+):
      - » 15 MHz (=75 carriers) to Wind; 7.5 (=37 carriers) to first and second operator (plus existing 27 GSM 900 carriers)

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Other GSM bands

➔ **Extended GSM (E-GSM) band**
- ⇨ Uplink: 880-915 MHz
- ⇨ Downlink: 925-960 MHz

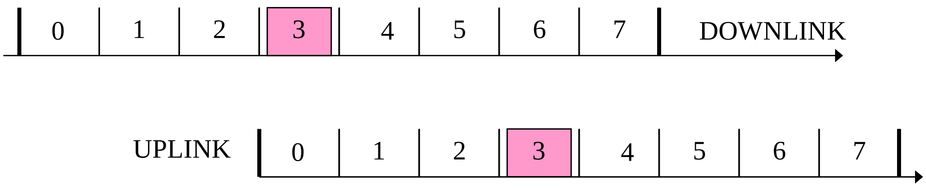
➔ **Other bands:**
- ⇨ 450 MHz → (450.4-457.6 up; 460.4-467.6 down)
- ⇨ 480 MHz → (478.8-486 up; 488.8-496 down)
- ⇨ 1900 MHz → (1850-1910 up; 1930-1990 MHz)

Duplexing

- MS uses SAME slot number on uplink and downlink

- Uplink and downlink carriers always have a 45 MHz separation
-I.e. if uplink carrier is 894.2 → downlink is 919.2

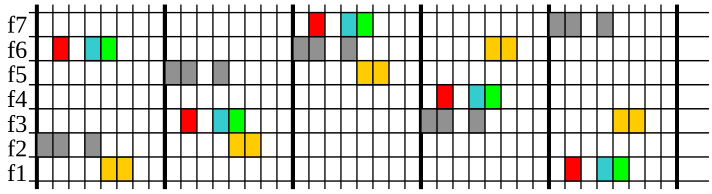
-3 slot delay shift!!



MS: no need to transmit and receive in the same time
on two different frequencies!

Slow Frequency hopping

(optional procedure within individual cell)



Hopping sequence (example):

… → f1 → f2 → f5 → f6 → f3 → f7 → f4 → *f1*…

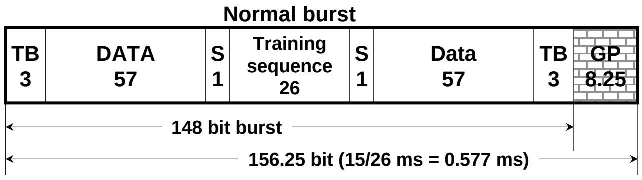
Slow = on a per-frame basis

- 1 hop per frame (4.615 ms) = 217 hops/second

Physical motivation:

- combat frequency-selective fading
- combat Co-Channel Interference
  - next slot may not interferere with adjacent cell slot (different hopping sequence)
- improvements: acceptable quality with 9 dB SNR versus 11 dB

Structure of a TDMA slot



→ **Symmetric structure**

→ **DATA: 2 x 57 data bits**

- ⇨ 114 data bits per burst
- ⇨ "gross" bits (error-protected; channel coded)
- ⇨ "gross" rate: 24 traffic burst every 26 frames (120 ms)
  - →22.8 kbps gross rate
  - →13 kbps net rate!

→ **S: 2 x 1 stealing bit**

- ⇨ Also called stealing flags, toggle bits
- ⇨ Needed to grab slot for FACCH (other signalling possible)

Tail & training bits

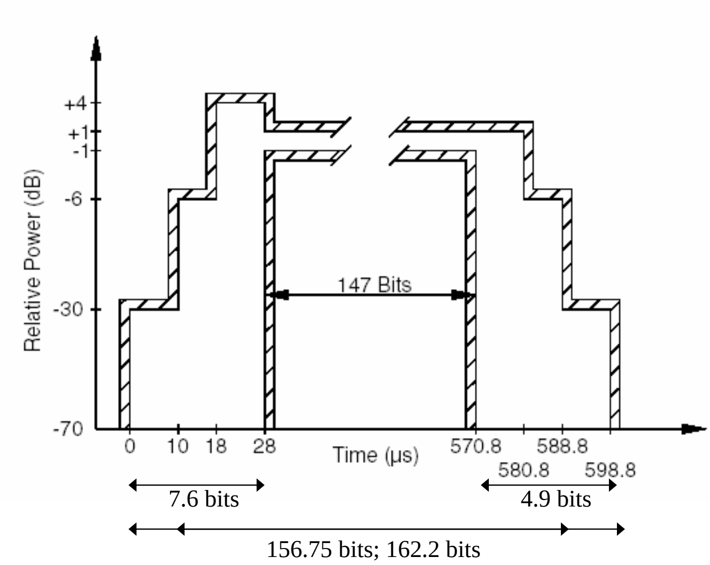
- ➔ **2 x TB = 3 tail bits set to 000**
  - ⇨ At start and end of frame
  - ⇨ Leave time available for transmission power ramp-up/down
  - ⇨ Assures that Viterbi decoding starts and ends at known state
- ➔ **26 bit training sequence**
  - ⇨ Known bit pattern (8 Training Sequence Code available)
  - ⇨ for channel estimation and synchronization
  - ⇨ Why in the middle?
    - →Because channel estimate reliable ONLY when the radio channel “sounding” is taken!
    - →Multipath fading rapidly changes the channel impulse response…

Training sequences

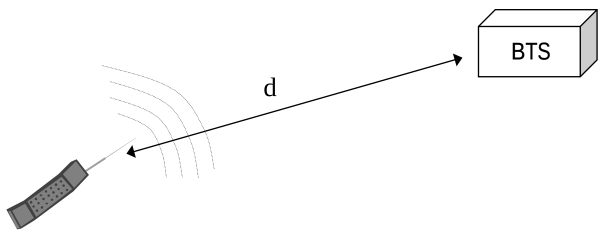
Training sequence code (TSC)	Training sequence bits (b61, b62, ..., b86)
0	(0,0,1,0,0,1,0,1,1,1,0,0,0,0,1,0,0,0,1,0,0,1,0,1,1,1)
1	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,1,0,0,0,1,0,1,1,0,1,1,1)
2	(0,1,0,0,0,0,1,1,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0)
3	(0,1,0,0,0,1,1,1,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0)
4	(0,0,0,1,1,0,1,0,1,1,1,0,0,1,0,0,0,0,0,1,1,0,1,0,1,1)
5	(0,1,0,0,1,1,1,0,1,0,1,1,0,0,0,0,0,1,0,0,1,1,1,0,1,0)
6	(1,0,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,1,0,0,1,1,1,1,1)
7	(1,1,1,0,1,1,1,1,0,0,0,1,0,0,1,0,1,1,1,0,1,1,1,1,0,0)

Different codes used in adjacent cells! Avoids training sequence Disruption because of co-channel interference.

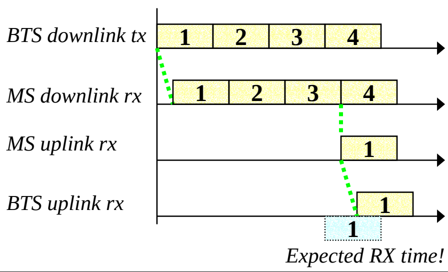
Power mask for Normal Burst



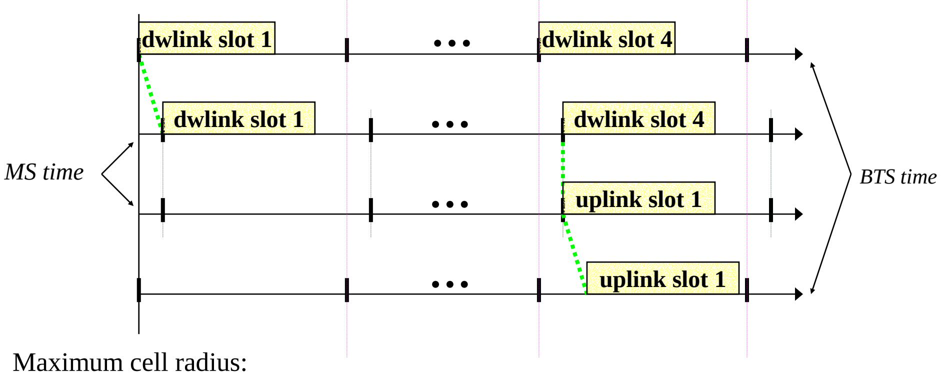
Guard Period rationale



- ➔ **Assume the following synchro mechanism:**
  - ⇨ BTS transmits at time 0
  - ⇨ MS receives at time d/c
  - ⇨ MS transmits at time 3+d/c
  - ⇨ BTS receives at time 3+ 2d/c
- ➔ **Offset depending on d!**



Guard period sizing

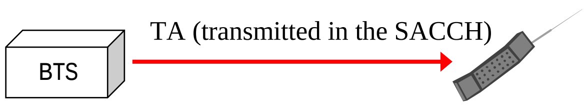


Maximum cell radius:

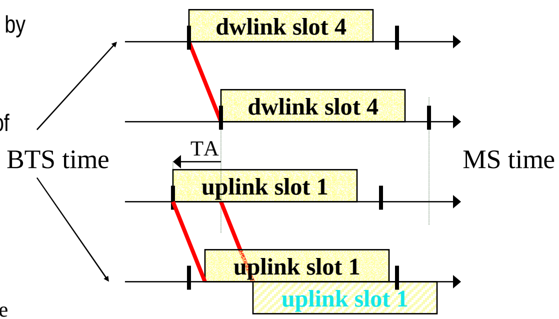
$$\frac{GT_{bits}}{C_{rate}} = \frac{2d}{c} \quad \rightarrow \quad d = \frac{c \cdot GT_{bits}}{2C_{rate}} \approx \frac{300000 \cdot 8.25}{2 \cdot 270833} \approx 4.5Km$$

Is there something wrong? (GSM says that cells go up to 35 km)

Frame synchronization



- **Timing Advance (TA)**
  - Parameter periodically transmitted by BTS during MS activity
  - 6 bits = 0-63
  - Meaning: anticipate transmission of TA bits
  - TA=0: no advance
    - → I.e. transmit after 468.75 bits after downlink slot
  - TA=63:
    - → Transmit after 405.75 bits time



TA avoids collision!

Timing Advance analysis

- **Downlink propagation delay:**
  - d/c
- **Uplink propagation delay:**
  - d/c
- **Uplink delay with TA:**
  - d/c-TA
- **Perfect resynchronization occurs when**
  - TA = 2d/c
- **Maximum cell size for perfect resync:**

$$d = \frac{TA}{2} \cdot c = \frac{31.5\,[bits]}{270833\,[bits/s]} \cdot 300000\,[km/s] = 34.89\,[km]$$

8.25 bits Guard time additionally available for imperfect sync (+/- error)

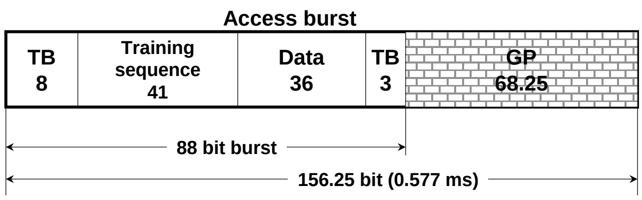
And when the user is not connected?

But wants to connect…

Solution: USE A DIFFERENT BURST FORMAT

Access Burst: much longer Guard Period available

drawback: much less space for useful information



No collision with subsequent slot for distances up to 37.8 km

Other burst formats in GSM

- ➔ **5 different bursts available**
  - ⇨ Normal Burst
  - ⇨ Access Burst

  - ⇨ Frequency Correction Burst
  - ⇨ Synchronization Burst
  - ⇨ Dummy Burst

Frequency Correction Burst

Frequency Correction Burst

TB 3	Fixed bit pattern (all 0s) 142	TB 3	GP 8.25

- ➔ **All 0s burst (TB=0, too)**
- ➔ **After GMSK modulation:**
  - ⇨ Sine wave at $f_{reference}$+1625/24 kHz (67.7083 kHz)
- ➔ **Acts as a "beacon"**
  - ⇨ When an MS is searching to detect the presence of a carrier
- ➔ **Allows an MS to keep in sync with reference frequency**

Dummy Burst

Dummy Burst

TB 3	Fixed bit pattern 58	Training sequence 26	Fixed bit pattern 58	TB 3	GP 8.25

- ➔ **Used to fill inactive bursts on the BCCH**
- ➔ **Guarantees more power on BCCH than that on other channels**
  - ⇨ Important, when MS needs to find BCCH

Synchronization Burst

Synchronization Burst

TB 3	Sync data 39	Training sequence 64	Sync data 39	TB 3	GP 8.25

- ➔ **Longer training sequence**
  - ⇨ It is the first burst an MS needs to demodulate!
  - ⇨ 1 single training sequence
- ➔ **Data field:**
  - ⇨ Contains all the information to synchronize the frame
    - → i.e. synchronize frame counter
  - ⇨ Contains the BSIC (Base Station Identity Code, 6 bits)
    - → 3 bits network code (operator)
      - » Important at international boundary, where same frequencies can be shared by different operators
    - → 3 bits color code
    - → To avoid listening a signal from another cell, thinking it comes from the actual one!

PART 4
GSM – Radio Interface

Lecture 4.2
logical channels

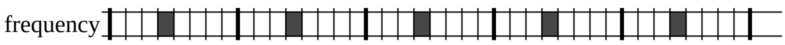
Logical vs Physical channels

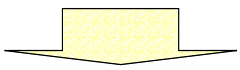
Logical channels (traffic channels, signalling (=control) channels)
Physical channels (FDMA/TDMA)

- **Physical channels**
  - Time slots @ given frequencies
  - Issues: modulation, slot synchronization, multiple access techniques, duplexing, frequency hopping, etc
- **Logical channels**
  - Built on top of phy channels
  - Issue: which information is exchanged between MS and BSS

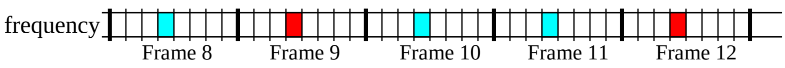
Logical – physical mapping

Physical Channel: data rate *r*, time slot *i*





Logical Channel Mapping:
Different channels may share a same physical channel



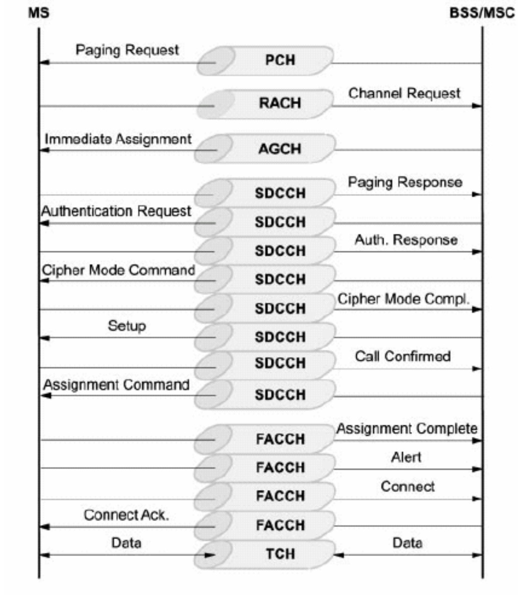
- Logical channel A: data rate *r/3*, time slot *i*, frame *3k*
- Logical channel B: data rate *2r/3*, time slot *i*, frame *3k+1, 3k+2*

GSM logical channels

Traffic channel (TCH)	**TCH/F**	TCH full rate	MS←→BSS
	TCH/H	TCH half Rate	MS←→BSS
Broadcast channel	**BCCH**	Broadcast control	BSS→MS
(same information to all MS in a cell)	**FCCH**	Frequency Correction	BSS→MS
	SCH	Synchronization	BSS→MS
Common Control channel (CCCH)	**RACH**	Random Access	MS→BSS
(point to multipoint channels)	**AGCH**	Access Grant	BSS→MS
(used for access management)	**PCH**	Paging	BSS→MS
Dedicated Control channel (DCCH)	**SDCCH**	Stand-alone Dedicated control	MS←→BSS
(point-to-point signalling channels)	**SACCH**	Slow associated control	MS←→BSS
(dedicated to a specific MS)	**FACCH**	Fast associated control	MS←→BSS

Additional logical channels available for special purposes
(SMS, group calls, …)

An example procedure involving signalling



Setup for an incoming call (call arriving from fixed network part - MS responds to a call)

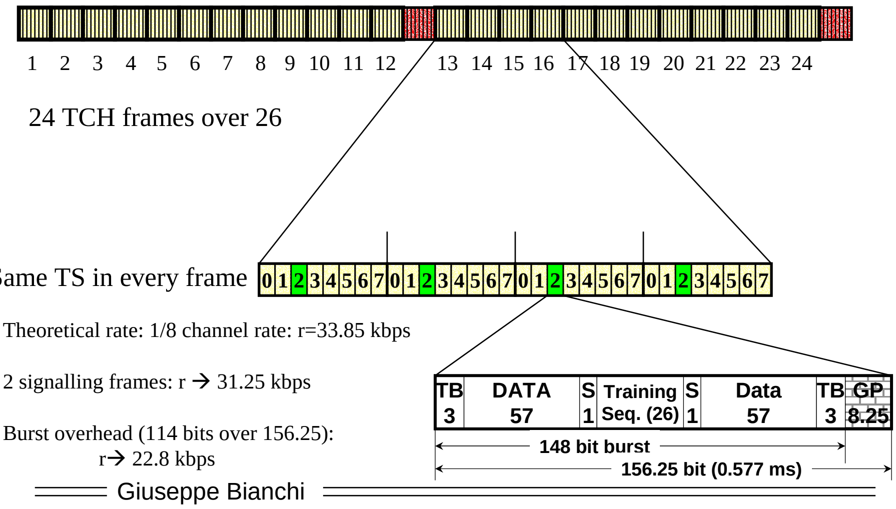
Steps:
- paging for MS
- MS responds on RACH
- MS granted an SDCCH
- authentication & ciphering on SDCCH
- MS granted a TS (TCH/FACCH)
- connection completed on FACCH
- Data transmitted on TCH

PART 4
GSM – Radio Interface

Lecture 4.3
Traffic channels and associated signalling channels

Traffic channels (TCH/F)

Periodic pattern of 26 frames (120 ms = 15/26 ms/TS * 8 TS/frame* 26 frame)



Theoretical rate: 1/8 channel rate: r=33.85 kbps

2 signalling frames: r → 31.25 kbps

Burst overhead (114 bits over 156.25):
r→ 22.8 kbps

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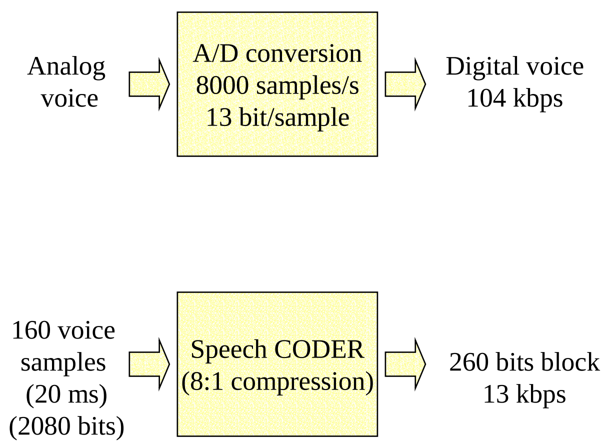
Speech coding



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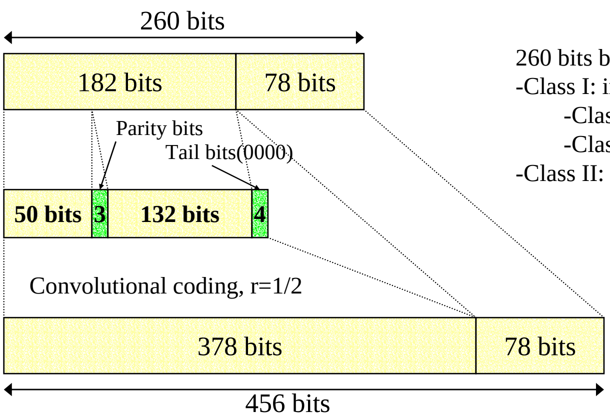
Discontinuous transmission

- **Speech coder implements Voice Activity Detection (VAD)**
  - Voice activity: idle for about 40% of the time
  - To avoid clipping: hangover period (80ms)

- **When IDLE, do not transmit**
  - Save battery consumption
  - Reduces interference
- **Receiver side: silence is disturbing!**
  - Missing received frames replaced with "comfort noise"
  - Comfort noise spectral density evaluated by TX decoder
  - And periodically (480ms) transmitted in special frame (SID= Silence Descriptor)

Channel Coding

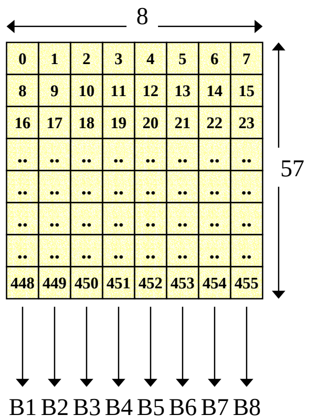
Coding: needed to move from 10^{-1} to 10^{-3} radio channel native BER down to acceptable range (10^{-5} to 10^{-6}) BER



260 bits block divided into
-Class I: important bits (182)
-Class Ia: Most important 50
-Class Ib: Less important 132
-Class II: low importance bits (78)

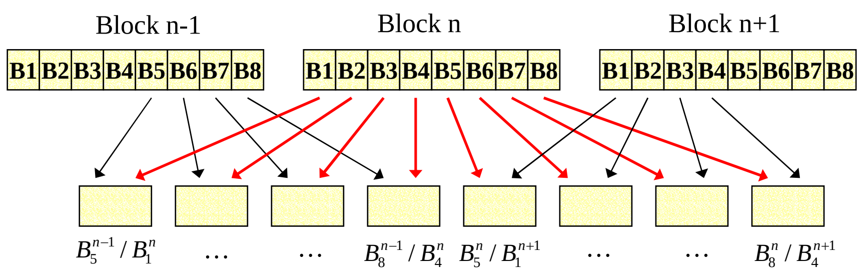
First step: block coding for error detection in class Ia (error→discard frame)
Second step: convolutional coding for error correction

Block interleaving



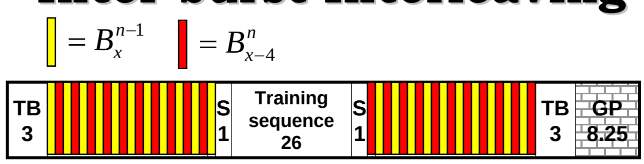
8 blocks, each with 57 bits

Diagonal Interleaving



PRICE TO PAY: delay!! (block spreaded over 8 bursts → 37 ms)

Inter-burst Interleaving

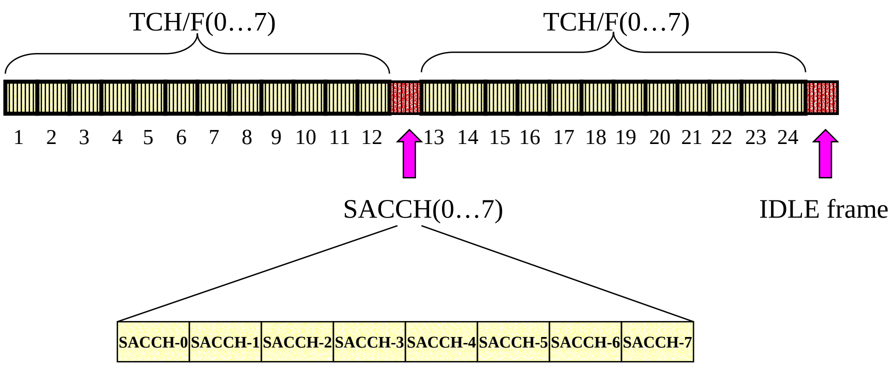


Bad Frame Indicator

- **When errors cannot be corrected:**
  - Frame must be discarded
- **In substitution, transmit speech frame**
  - predictively calculated
  - No more than 16 consecutive BFI
    - If this happens, receiver muted

Slow Associated Control Channel

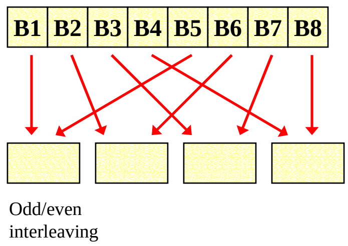
- Always associated to instaurated call on TCH (TCH + SACCH = TACH)
  - On the same Time Slot
- Periodic (order of ½ second) time-scale information for radio link control

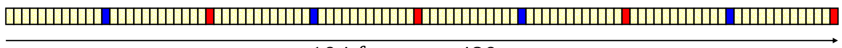


1 SACCH burst (per TCH) every 26 frames (120 ms)

SACCH block

- ➔ **184 signalling bits**
  - →Block coding adds 40 bits (=224)
  - →4 tail (zero) bits (=228)
  - →1/2 Convolutional encoding (=456 bits)
- ➔ **Interleaving:**
  - ⇨ 8 blocks of 57 bits;
  - ⇨ spreaded into four consecutive bursts
  - ⇨ 4 bursts = 1 and only 1 SACCH block!
- ➔ **SACCH rate:**
  - ⇨ 184 bits/480 ms = 383.3 bit/s





104 frames = 480 ms

SACCH contents

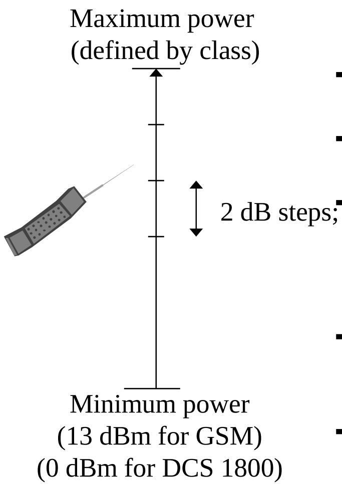
- ➔ **184 bits = 23 bytes**

- ➔ **Power level**
- ➔ **Timing advance**
- ➔ **Measurement reports for link quality**
- ➔ **Measurement reports for handover management**

- ➔ **When available space: SMS**
  - ⇨ When call in progress!

0	1	2	3	4	5	6	7
free			Power level				
free	Timing advance						
(21 bytes – datalink layer) Includes measurement reports							

Power control



- ➔ **MS has ability to reduce/increase power**
  - ⇨ Up to its power class maximum
- ➔ **Maximum one 2 dB step every 60 ms**
- ➔ **uplink power measures taken by BTS**
- ➔ **notified back to MS via SACCH**
  - ⇨ Power level values: 0-15
    - →0 = 43 dBm (20 W)
    - →15 = 13 dBm (20 mW)
- ➔ **algorithm: manifacturer specific**
  - ⇨ runs on BSC
- ➔ **power control applied also on downlink**

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Measurement values

- ➔ **RXLEV**
  - ⇨ Power level
  - ⇨ Present channel + neighbohr cell)

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	-

- ➔ **RXQUAL**
  - ⇨ Bit Error Rate (raw)

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	-

Averaged over 1 SACCH block (480ms = 104 frames)

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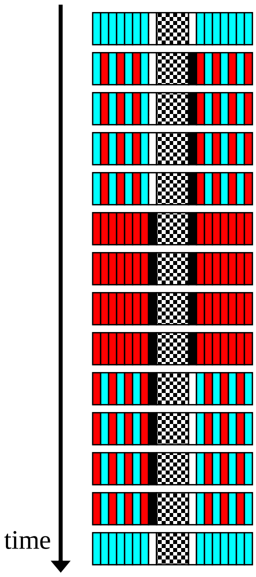
Fast Associated Control Channel

- ➔ **FACCH: urgent signalling**
  - ⇨ Used when several signalling information needs to be transmitted
    - →Call setup
    - →Handover
- ➔ **FACCH block = 184**
  - ⇨ 456 after coding
- ➔ **Interleaved as voice block**
  - ⇨ Spreaded on 8 bursts
- ➔ **Replaces a voice block (20 ms) on the TCH**
  - ⇨ Via stealing bits
  - ⇨ Voice block(s) discarded
- ➔ **Maximum FACCH bit rate**
  - ⇨ 184*6/120 [bits/ms] = 9.2 kbps (vs 383 bps of SACCH!)

FACCH insertion in TCH

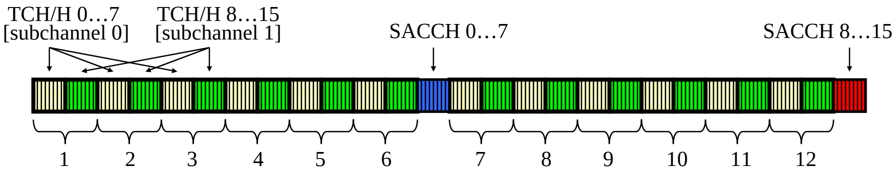


Via Stealing bits
- upper bit = odd bits stolen
- lower bit = even bits stolen
- both bits = all burst stolen

Figure: shows example of 2 FACCH blocks stealing a TCH (note begin and end behavior due to interleaving)

Half-rate traffic channels (TCH/H)

- ➔ **Support for 5.6 kbps voice codecs**
- ➔ **Specification in 1995**
- ➔ **228 bits block**
  - ⇨ 112 bits of compressed 20ms voice
    - → 95 bits class I
      - » + 3 parity + 6 tail + convolutional coding 104/211
    - → 17 bits class 2
- ➔ **Interleaving:**
  - ⇨ Same as voice (block + diagonal + odd/even)
  - ⇨ But on 4 bursts
- ➔ **Framing:**



Other traffic channels

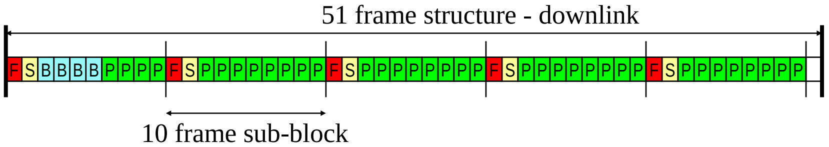
- ➔ **TCH data**
  - ⇨ Basic speed: 9.6 kbps (data,fax)
  - ⇨ Other speeds: <2.4; 4.8; 9.6; 14.4;
- ➔ **Different coding details**
  - ⇨ See text(s)
- ➔ **Major difference with voice:**
  - ⇨ Interleaving with depth = 19 (!!!)
  - ⇨ complete fading of a burst is recoverable (unlike voice)

PART 4
GSM – Radio Interface

Lecture 4.4
Broadcast Carrier and Channels

Broadcast Channel (usual) organization

- ➔ **51 frame structure vs 26**
  - ⇨ 235.38 ms period (vs 120 ms)
- ➔ **Sub-blocks with 10 frames**
  - ⇨ Starting with Frequency Correction Channel (FCCH)
  - ⇨ Immediately followed by Synchronization Channel (SCH)
- ➔ **Other frames** (numbered from #0 to #50)**:**
  - ⇨ #50 idle
  - ⇨ #2,3,4,5 BCCH
  - ⇨ Remaining: Paging (PCH) / Access Grant (AGCH) [=PAGCH]

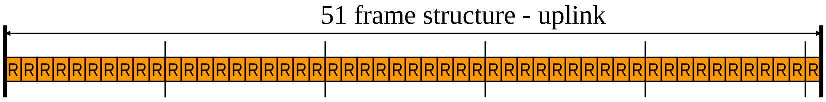


BCCH carrier placement

➔ **On Downlink**

⇨ Corresponding uplink dedicated to Random Access Channel

51 frame structure - uplink



➔ **On one frequency per cell (beacon)**

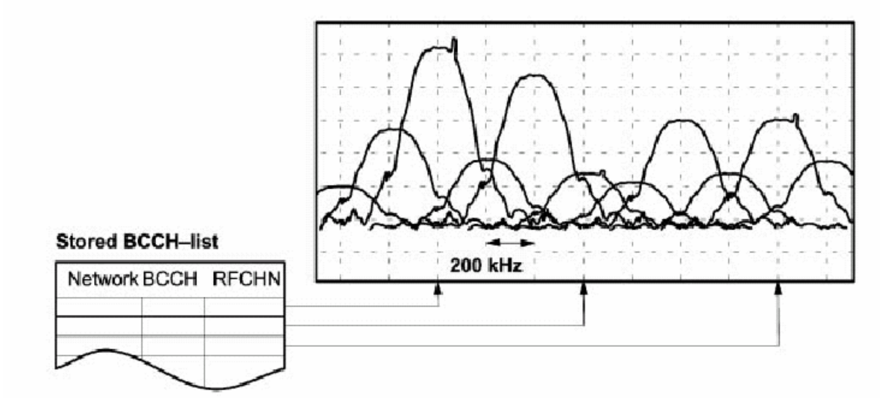
➔ **MUST BE on Time Slot #0**

➔ **Other Time slots may be used by TCH**

Provided that:

- All empty slots are filled with DUMMY bursts
- Downlink power control must be disabled

MS powering up



First operation when MS turned ON: spectrum analysis

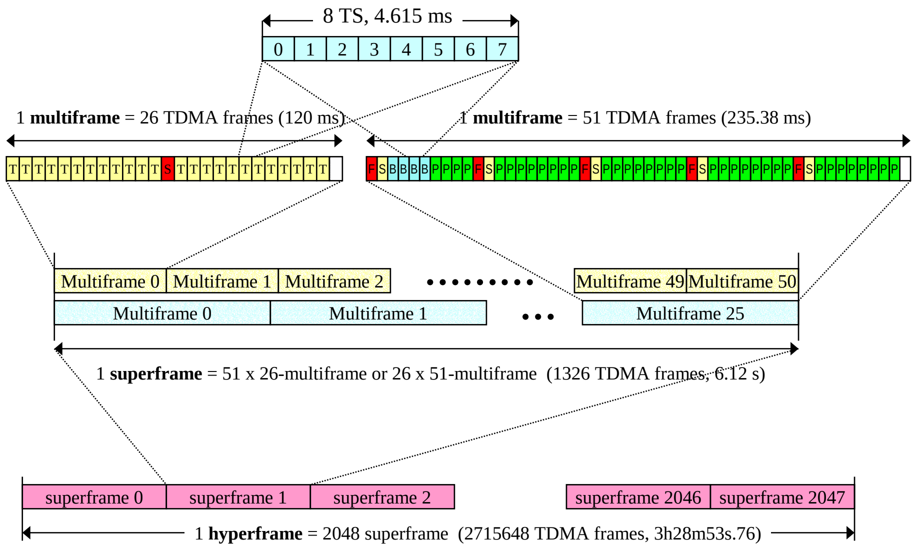
(either on list of up to 32 Radio Frequency Channel Numbers of current network)

(or on whole 124 carriers spectrum)

tuning

- ➔ **MS listens on strongest beacon for a pure sine wave (FCCH)**
  - ⇨ Coarse bit synchronization
  - ⇨ Fine tuning of oscillator
- ➔ **Immediately follows SCH burst**
  - ⇨ Fine tuning of synchronization (64 bits training sequence)
  - ⇨ Read burst content for synchronization data
    - → 25 bits (+ 10 parity + 4 tail + ½ convolutional coding = 78 bits)
    - → 6 bits: BSIC
    - → 19 bits: Frame Number (reduced)
- ➔ **Finally, MS can read BCCH**

Multi-framing structure



Why frame number?

FN =	Superframe #	Multiframe #	frame #

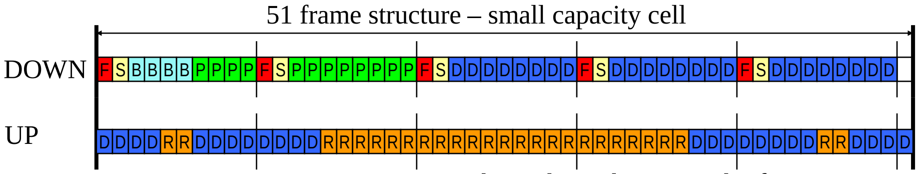
- ➔ **Frame #**
  - ⇨ Distinguishes logical channels in the same physical channel
- ➔ **Multiframe #**
  - ⇨ Determines how BCCH is constructed
    - → I.e. which specific information transmitted on BCCH during a given multiframe
- ➔ **Superframe #**
  - ⇨ Used as input parameter by encyphering algorithm

BCCH contents

- ➔ **184 bits**
  - ⇨ Coded in 456 bits and interleafed in 4 bursts
  - ⇨ same coding and interleaving as SACCH
  - ⇨ BCCH capacity
    - → 184 bits / (51*8*15/26 ms) ~ 782 bps
- ➔ **Information provided**
  - ⇨ Details of the control channel configuration
  - ⇨ Parameters to be used in the cell
    - → Random access backoff values
    - → Maximum power an MS may access (MS_TXPWR_MAX_CCCH)
    - → Minimum received power at MS (RXLEV_ACCESS_MIN)
    - → Is cell allowed? (CELL_BAR_ACCESS)
    - → Etc.
  - ⇨ List of carriers used in the cell
    - → Needed if frequency hopping is applied
  - ⇨ List of BCCH carriers and BSIC of neighboring cells

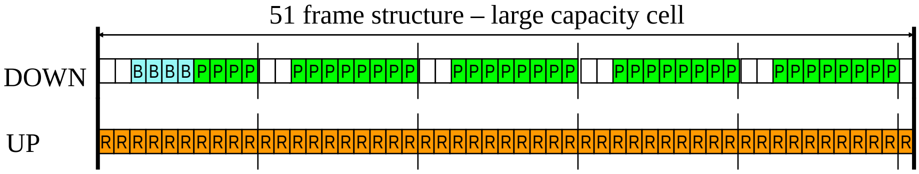
control channel alternative organization

51 frame structure – small capacity cell



Integrates SDCCH in same channel as other control information
Leaves additional TS all available for TCH

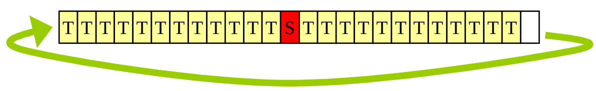
51 frame structure – large capacity cell



Used in TS 2 (and, eventually, 4 and 6) of beacon carrier
Provides additional paging and RACH channels

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 superframe

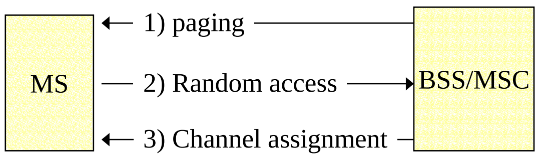
- important slots while call is active: frequency correction FCCH and sync SCH!
- needed for handover
    -Worst case: at most every 11 TCH multiframes (1.32 s), there will be
     a frequency correction burst of a neighboring cell

PART 4
GSM – Radio Interface

Lecture 4.5
Paging, Random Access, dedicated signaling

Why paging

- ⇨ Channel assignment:
  - → only upon explicit request from MS
- ⇨ Paging
  - → needed to "wake-up" MS from IDLE state when incoming call arrives to MS
- ⇨ MS accesses on RACH to ask for a channel
  - → Generally SDCCH (but immediate TCH assignment is possible)



Paging channel:	PCH	PAGCH	CCCH Common Control CHannel
Access Grant Channel:	AGCH		
Random Access Channel:	RACH		

Giuseppe Bianchi

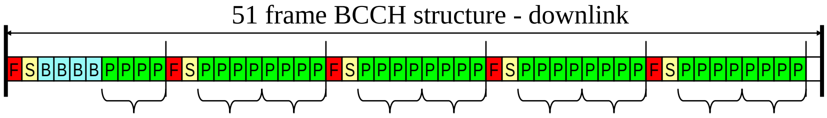
Paging

- ➔ **Paging message generated by MSC**
  - ⇨ Which receives incoming call
- ➔ **Transferred to subset of BSC**
  - ⇨ Paging limited to user's location area
  - ⇨ Paging message contains:
    - →List of cells where paging should be performed
    - →Identity of paged user (IMSI or TMSI)
- ➔ **Paging message coded in 4 consecutive bursts over the air interface**
  - ⇨ Same coding/interleaving structure of SACCH (184→456 bits)
- ➔ **Paging for more MSs may be joined in one unique paging message**

Discontinuous Reception (DRX)

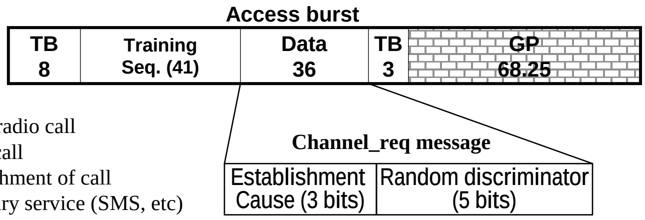
- ➔ **MS in idle mode should listen to paging channel**
- ➔ **To save battery, PCH divided into sub-channels**
  - ⇨ Subdivision based on last 3 digits of IMSI
  - ⇨ User listens only to relevant sub-channel
    - →Switches off otherwise
- ➔ **PCH sub-channels pattern communicated on BCCH**
  - ⇨ Up to 9 sub-channels

51 frame BCCH structure - downlink



Access procedure

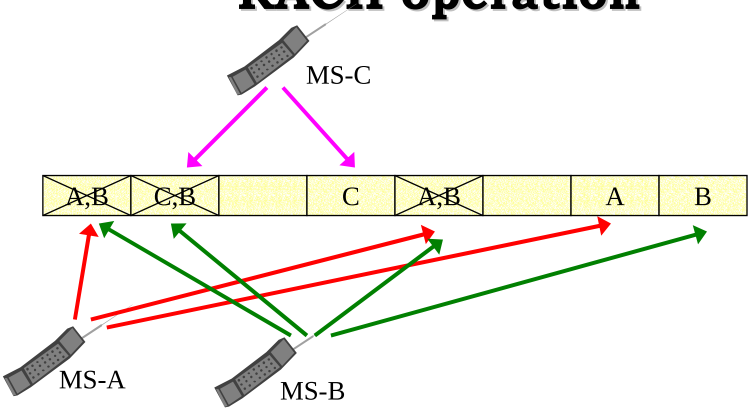
- ➔ **Always activated by MS**
  - ➪ In response to paging (incoming call)
  - ➪ When location update needs to be performed
  - ➪ When new call is generated by MS
- ➔ **Based on access burst sent on RACH**
  - ➪ Access burst coding: 8 payload bits (channel_req) → 36 coded bits
    - →+6 parity; + 4 tail; + ½ convolutional coding



100: response to radio call
101: emergency call
110: new establishment of call
111: supplementary service (SMS, etc)
…
000: other case

Random discriminator: (0…31) value randomly generated by MS

RACH operation



Multiple Access Technique for simultaneous access
Collision resolution based on
- random retrial period
- “permission” probability

} Same thing..!

(SLOTTED ALOHA protocol)

RACH performance

- **N stations**
- **Each transmits with probability p**
  - Retries, in average, every 1/p slots
- **relevant probabilities:**

$$\text{idle}: \quad (1-p)^N$$

$$\text{success}: \quad Np(1-p)^{N-1}$$

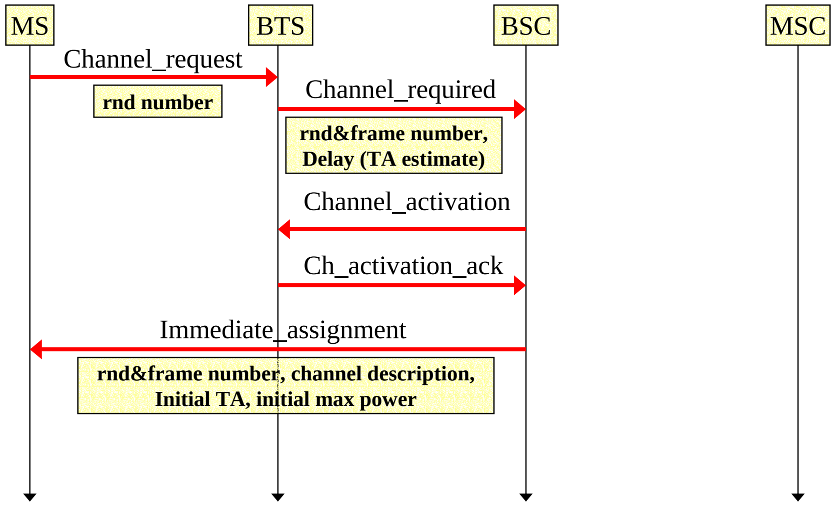
$$\text{collision}: \quad \sum_{k=2}^{N} \binom{N}{k} p^k (1-p)^{N-k}$$

Maximum efficiency: when p=1/N

RACH performance control

- **BCCH broadcasts**
  - Backoff time
    - uniform distribution; max value: 3 to 50
  - Maximum number of retransmission attempts
    - Never greater than 7
- **May also specify:**
  - time interval for a retry after failure (default=5s)
  - RACH group access control
    - MSs divided into 10 groups, depending on SIM-related information
    - BTS may block selected groups
    - Allows to reduce RACH load down to as low as 10%
      - » Emergency calls bypass this rule…

Access signaling - 1

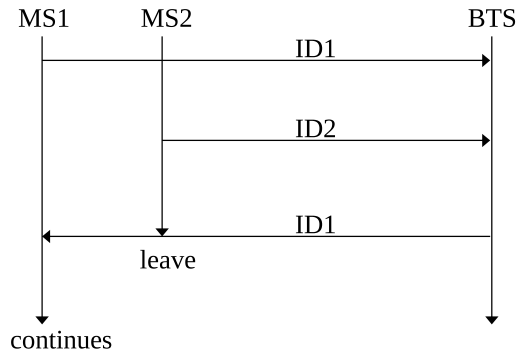


Immediate Assignment message

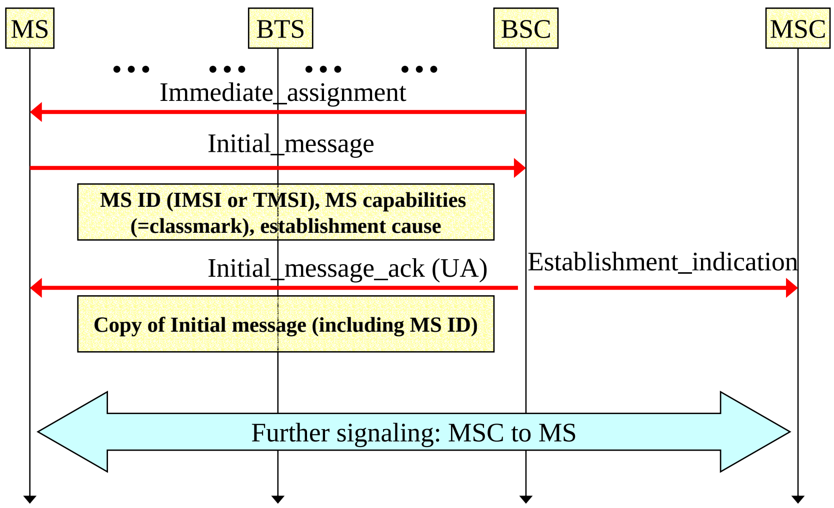
- ➔ **on paging channel**
  - ⇨ I.e. AGCH is a dynamically mapped channel
    - – name PAGCH is perhaps better…
- ➔ **Sent "as soon as possible"**
  - ⇨ MS continues accessing the RACH
  - ⇨ Message scheduling is an implementation dependent issue
    - → I.e. which message to send in case of many messages, and on which paging slot (4 bursts)
  - ⇨ MS must disable DRX
    - → To monitor PAGCH for Immediate Assignment message detection
- ➔ **Immediate assignment reject possible**

If same random discriminator?

- ➔ two MSs may have same random discriminator
  - ⇨ Likely in heavy load, with only 5 bits
- ➔ And transmit in the same frame
- ➔ Only one wins (the other is faded)
- ➔ contention resolved via explicit MS identification
  - ⇨ On SDCCH



Access signaling - 2



Stand-alone Dedicated Control Channel - SDCCH

- ➔ **Dedicated bidirectional channel to MS**
  - ⇨ but used to exchange signalling
- ➔ **Has an associated SACCH**
- ➔ **Coding: as SACCH**
  - ⇨ 184→456 bits on 4 consecutive bursts
- ➔ **Typical framing (SDCCH / 8)**
  - ⇨ 8 SDCCH (+8 SACCH) on 1 channel (carrier,TS)
  - ⇨ 1 SDCCH message per 51-multiframe
    - →184 bits / (51*8*15/26 ms) = 598/765 kbps ~ 782 bit/s
  - ⇨ 1 SACCH every 2 multiframe

SDCCH/4 for small cells – SDCCH shares BCCH+PAGCH channel - see before -