GSM Network and Services

Logical and physical layer

- how waves turn into reliable bits and bits into logical channels

Logical channels

- Defined at layer 1 and provided for layer 2
  - except the frequency correction channel and the synchronization channel.
- Mapped on the physical channels:
  - more than one logical channel can be mapped on one physical channel
  - mapped in time and coding
  - channels can be up, down or duplex
- Layer two of the signalling layer (LAPDm) can add acknowledgement and retransmission.

The logical channels

- Traffic channels - TCH
  - Full rate used for 13kbps voice or up to 14.4kbps data
  - Half rate used for 6.5kbps voice or low rate data
- Signalling channels
  - Broadcast channels - BCH
  - Common Control Channels - CCH
  - Dedicated Control Channels - DCH

Broadcast Channels

- Frequency Correction Channel (FCCH)
  - only visible at physical layer, helps the mobile tune in to the right frequency
- Synchronization Channel (SCH)
  - Helps the mobile stay synchronized with the base station, also carries the base station identity code (colour codes)
- Broadcast Control Channel (BCCH)
  - Information about the cell, neighbouring cells, location area identifier, structure of the Common Control Channels

Common Control Channels

- Random Access Channel (RACH)
  - for the mobiles to request access
- Access Grant Channel (AGCH)
  - for BSC to grant access
- Paging Channel (PCH)
  - for BSC to page a mobile
- Notification Channel (NCH)
  - for the BSC to notify a group of mobiles of Voice Broadcast Services

Dedicated Control Channels

- Stand alone Dedicated Control Channel (SDCCH)
  - duplex point to point signalling channel
- Associated Control Channels
  - Always allocated together with a traffic channel or signalling channel Will control the performance of the channel.
  - Slow (SACCH)
  - Fast (FACCH), only with TCH, used for handover

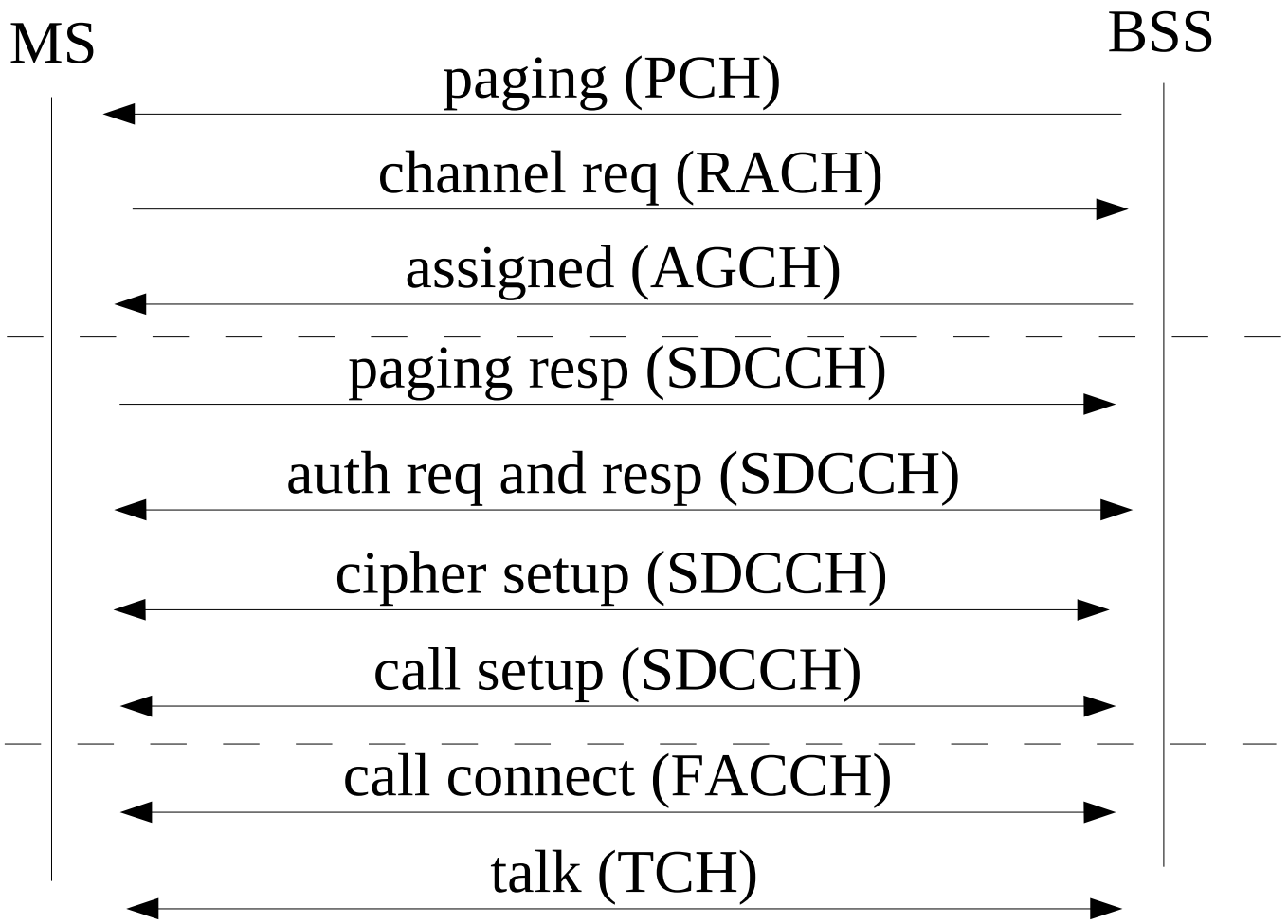
Cell Broadcast Channel

- Use to send out SMS broadcast messages, for example the “KTH/Monaco” that shows up in the screen when you connect to the Monaco network.

Mapping of logical channels

- TCH/F + FACCH + SACCH
  - needs a full physical channel
- TCH/H + FACCH + SACCH
  - half a physical channel
- SDCCH + SACCH
  - eight channels in one physical
- BCH (BCCH/FCCH/SCH) +
  CCCH (RACH/PCH/AGCH/NCH)
  - one physical channel, the broadcast channel
- A cell always needs a Broadcast channel.

Incoming call



Radio – bits - channels

- Modulation
  - how do we modulate our carrier
- Multiple access and duplex
  - time/frequency division and random access
  - frequency/time synchronization
- Logical channels
  - mapping to the physical channels

GSM radio modulation

0101101000100101111001010

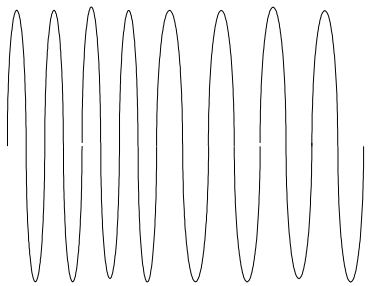
differential encoding

..11101110011011100010111 1

symbol coding

/2 0 /2 - - /2 - - /2 0 + /2

carrier modulation



Symbol modulation

- GSM uses GMSK
  - Gaussian Minimum Shift Keying
- Each bit is coded as one symbol so we have two symbols to code. Each symbol is codes as a ± /2 shift in phase e.g. Not an absolute phase but a increase or decrease in the phase.
- A shift in phase is gradual (Gaussian) and spread over more than one symbol duration.

Symbol coding

1 0 1 1 0 1 0 0 0

/2 + /2 /2 - /2 + /2 - /2 + /2 + /2 + /2

phase shift

/2 0 /2 - - /2 - - /2 0 + /2

resulting phase

What if we interpret one symbol 180 degrees (radians) wrong

sender

/2 + /2 /2 - - /2 - - /2 0 + /2

receiver

/2 0 /2 0 - /2 - - /2 0 + /2

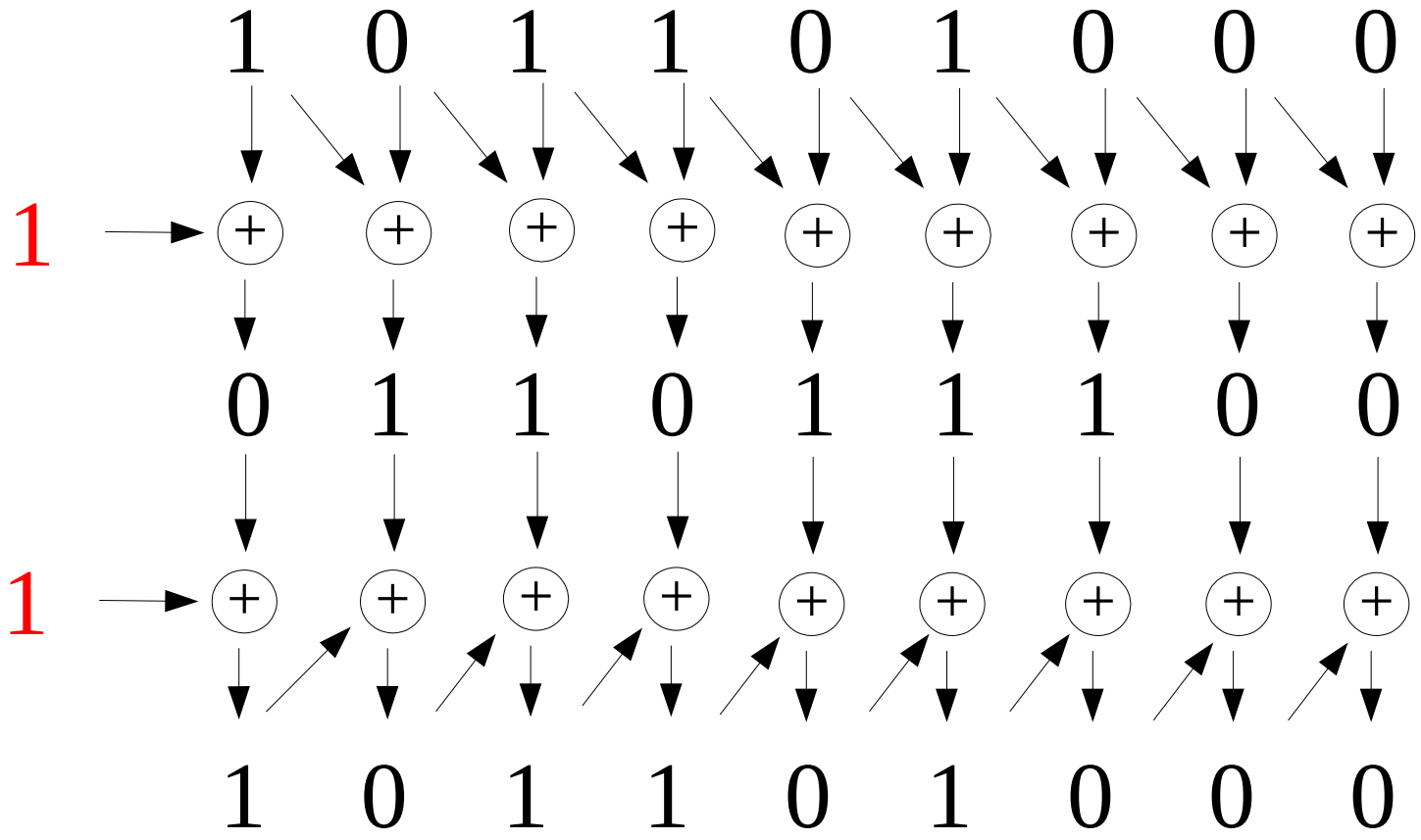
decoding

/2 + /2 /2 + /2 - /2 - /2 + /2 + /2 + /2

two bit errors!

1 0 1 0 1 1 0 0 0

Differential encoding



Differential encoding

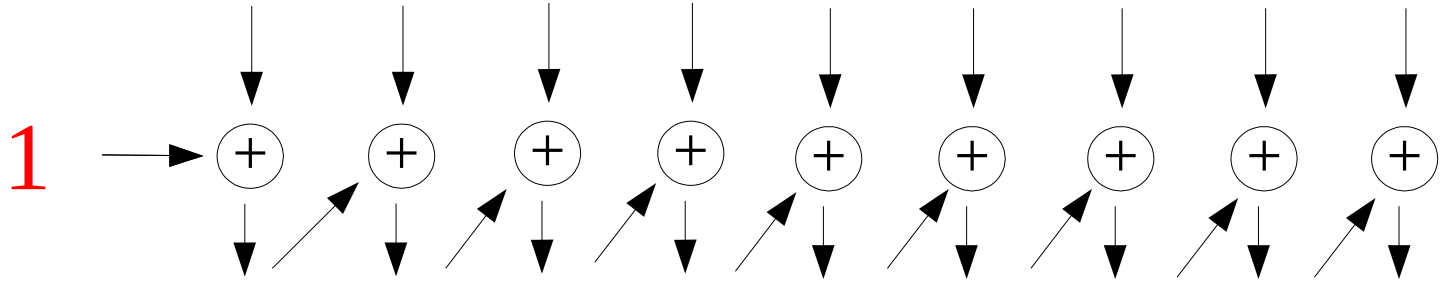
sender

0 1 1 0 1 1 1 0 0

(one symbol error results in two bit errors)

receiver

0 1 0 1 1 1 1 0 0



1 0 0 1 0 1 0 0 0

decoded we are back at one bit error.

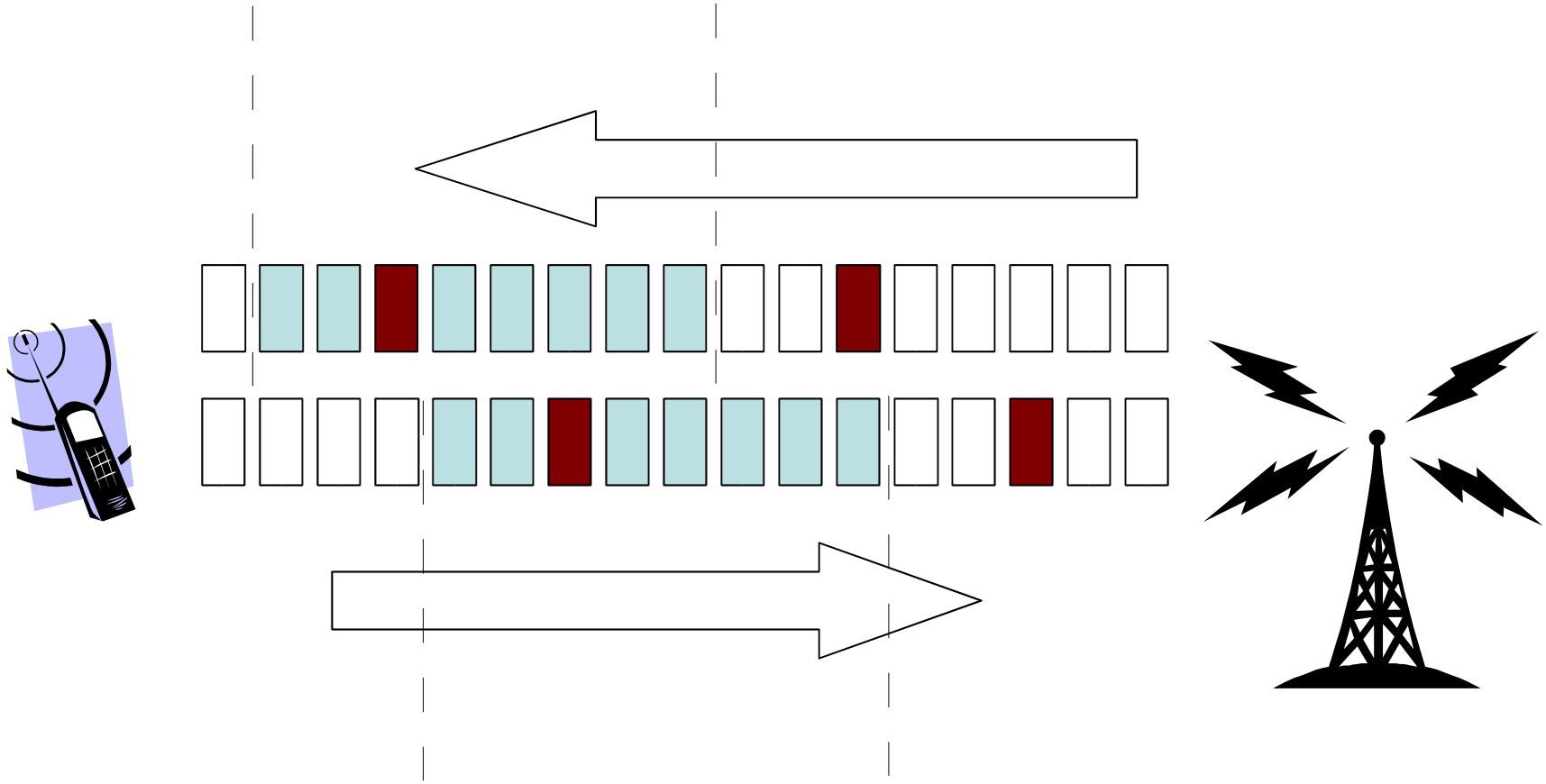
Carrier modulation

- Each carrier is 200 kHz wide.
- The symbol rate 271 kBaud.
- GMSK can also be seen as a Frequency Shift Keying (FSK) modulation using two frequencies ± 68 kHz from the central frequency.
- Note: 271 kBaud / 4 = 68 kHz, this is a property of “minimum”.

Duplexing and Multiple access

- One duplex channel consist of one up-link and one down-link carrier.
- Distance between the up/down link carrier is always 45MHz (in the 900 band).
- Each carrier is divided into radio frames and each frame is divided into eight time slots.
- A physical channel is a specified time slot in consecutive frames.
- The up link carrier is delayed three time slots. No need for a duplex transceiver!

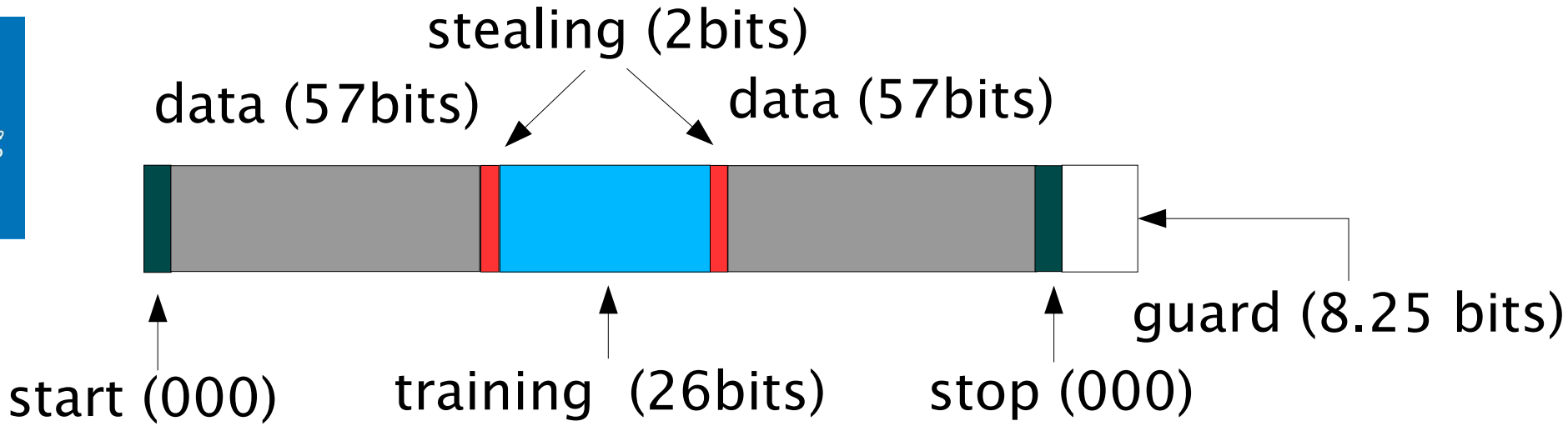
Duplex and Multiple access



Burst

- Since mobiles take turn sending the will send in bursts. Each burst will fit into a time slot.
- There are five types of bursts:
  - Normal
  - Frequency correction
  - Synchronization
  - Dummy
  - Access

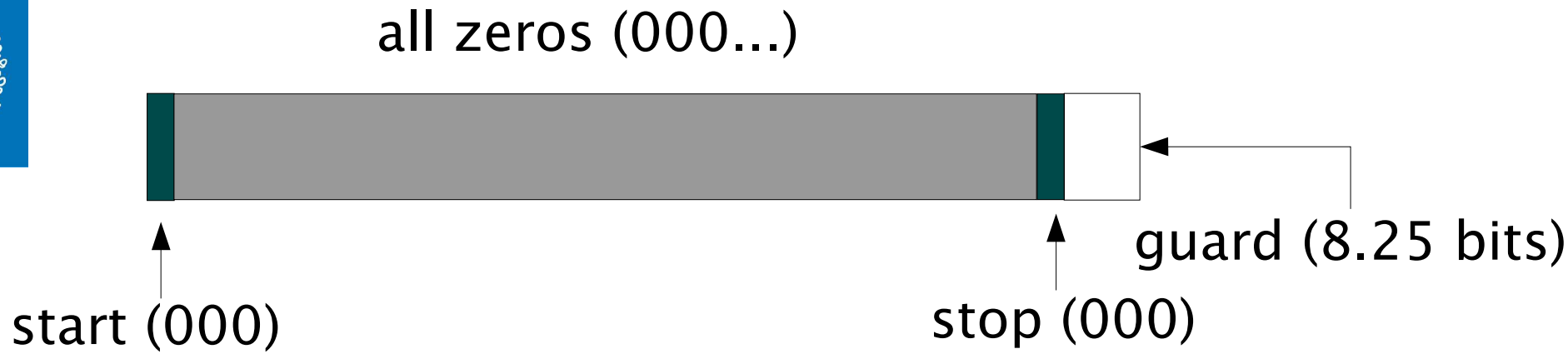
Normal burst



Normal burst

- 114 bits of user data
- Tow stealing flags for FACCH
- Training sequence used for synchronization and resolve inter-symbol interference.
  - The training sequence can be changed by layer three protocols.
- Enough space behind the burst so the sender can be a bit late (far away) and still not interfere with the following time slot.

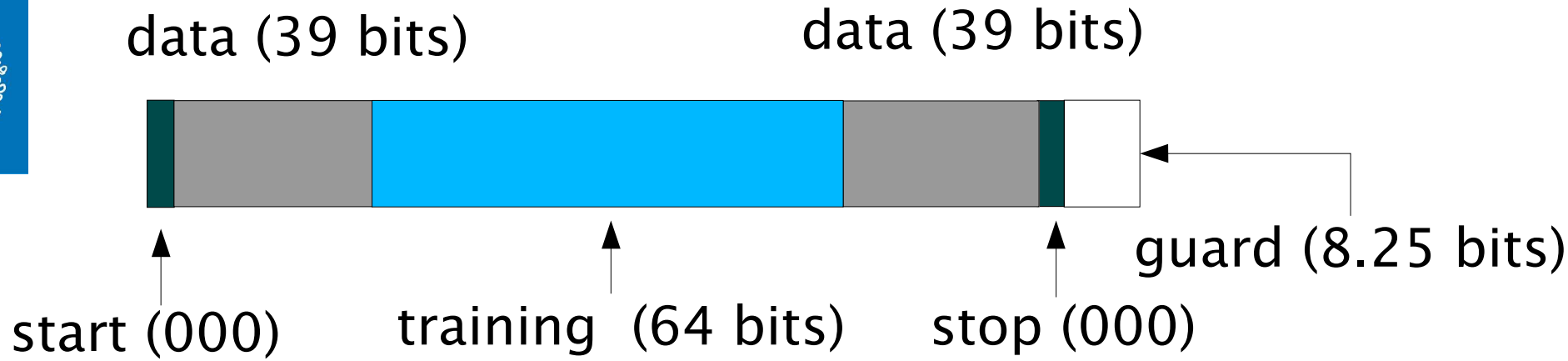
Frequency correction burst



Frequency correction burst

- A sequence of zeros will after differential encoding and phase modulation result in a constant negative phase shift.
- The constant phase shift will also be visible as a frequency shift to a perfect sine wave 68 kHz above the carrier frequency.
- A mobile can detect this sine wave and tune in to the frequency of a base station.

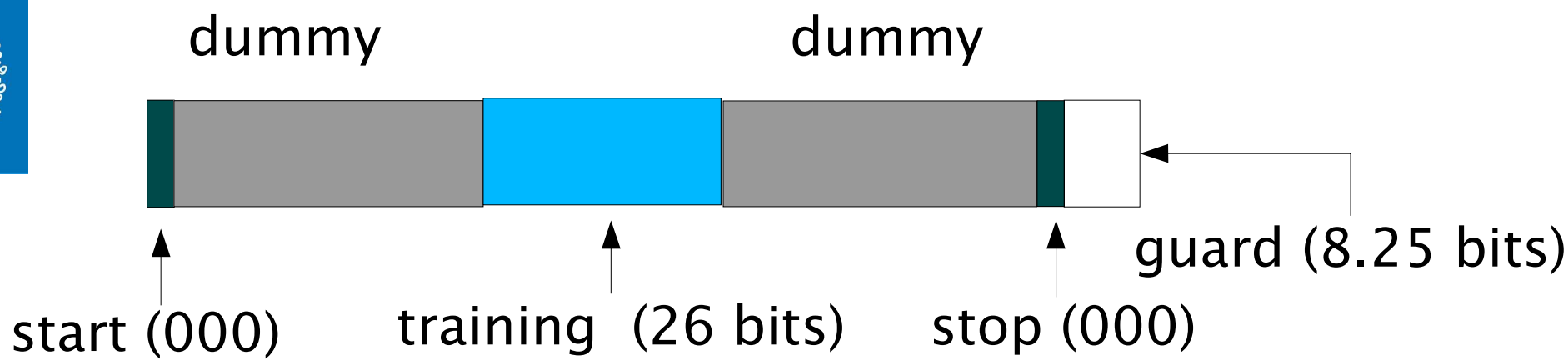
Synchronization burst



Synchronization burst

- A longer training sequence so that the mobile can do better synchronization.
- The data fields holds information about:
  - the sequence number off the frame
  - the colour codes of the cell (BSIC)

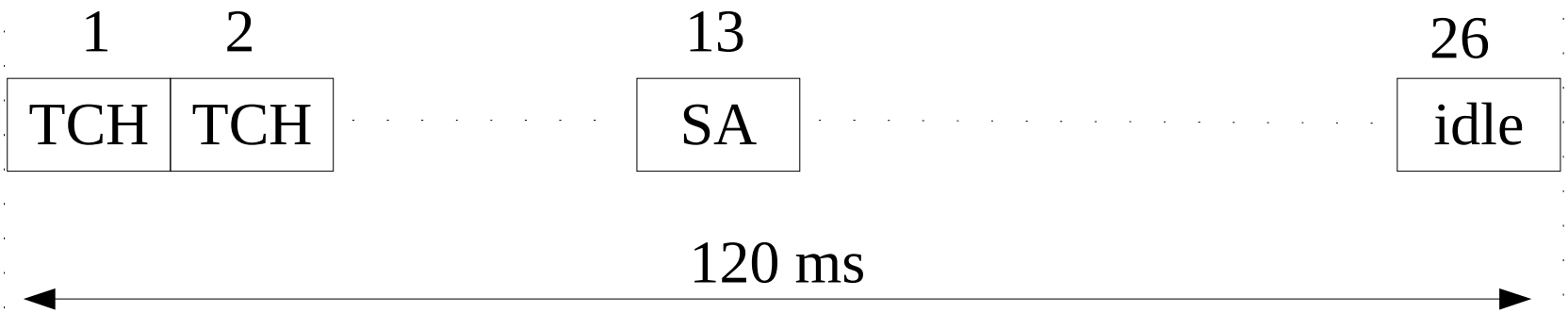
Dummy burst


dummy
dummy
guard (8.25 bits)
start (000)
training (26 bits)
stop (000)

Finding the Broadcasting control channel

- One carrier of each cell will carry the broadcast channel (BCCH/SCH/FCCH).
- Idle time slots of the carrier will be filled with dummy burst e.g. the broadcast carrier is always among the strongest carriers.
- The frequency correction burst will allow the mobile to identify and tune in to the carrier.
- The synchronization burst is found and the BSIC and frame number can be identified.
- Ready to listen for the BCCH.

Mapping of traffic channel



A physical channel is a specified time slot. Following this time slot in consecutive frames we have a sequence. Number this sequence mod 26, the traffic channel will occupy 1-12 and 14-25. The slow associated control channel occupy number 13, frame 26 is idle.
The fast associated control channel is implemented using “stealing flags” in the traffic channel.

Broadcast control channel

- The broadcast channel group the FCCH/SCH/BCCH and CCCH in a pattern of a 51 frame multiframe
- How does this align with the traffic channel that uses a 26 frame multiframe?

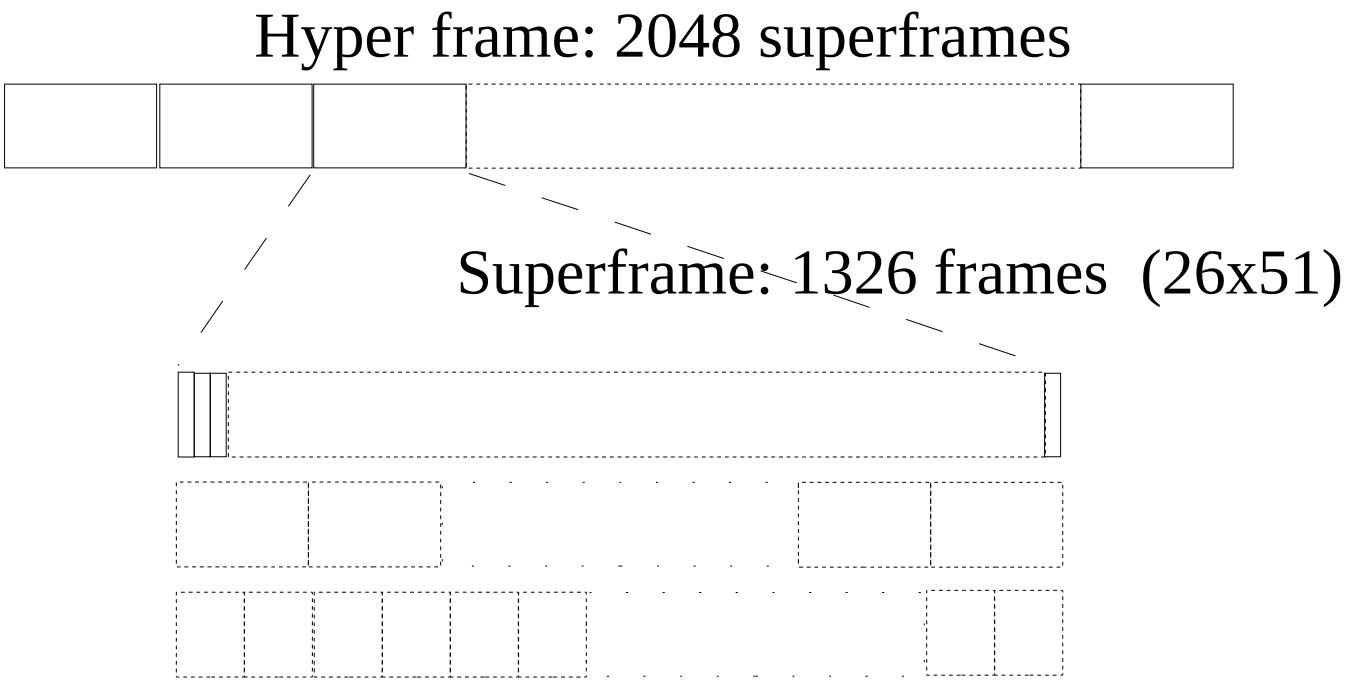
FSBBBBCCCCFSCCCCFSCCCCCCCCFSCCCCCCCCFSCCCCCCCC-

Frame numbering

- All frames are numbered and knowing the frame number you will know the sequence of logical channels in a multiframe.
- The frame number modulo 51 will give us an index in a signalling multiframe.
- The frame number modulo 26 will give us an index in a traffic multi frame

Frame numbering

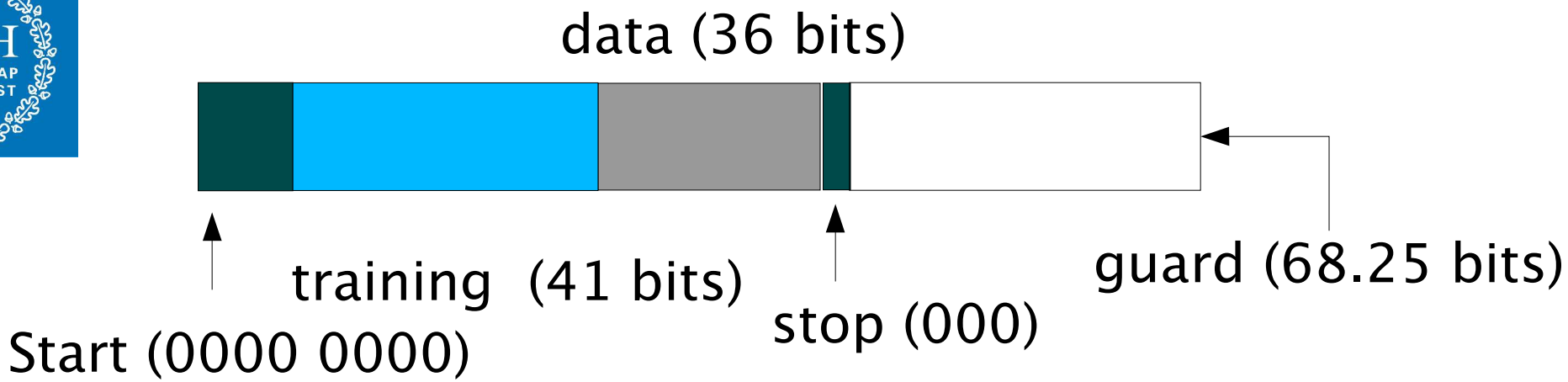
T3 is sent using only three bits?



T1 : superframe number [0 – 2047]
T2 : frame number mod 26
T3 : frame number mod 51

FN = T1x26x51 + ((T3 – T2) mod 26) x 51 + T3

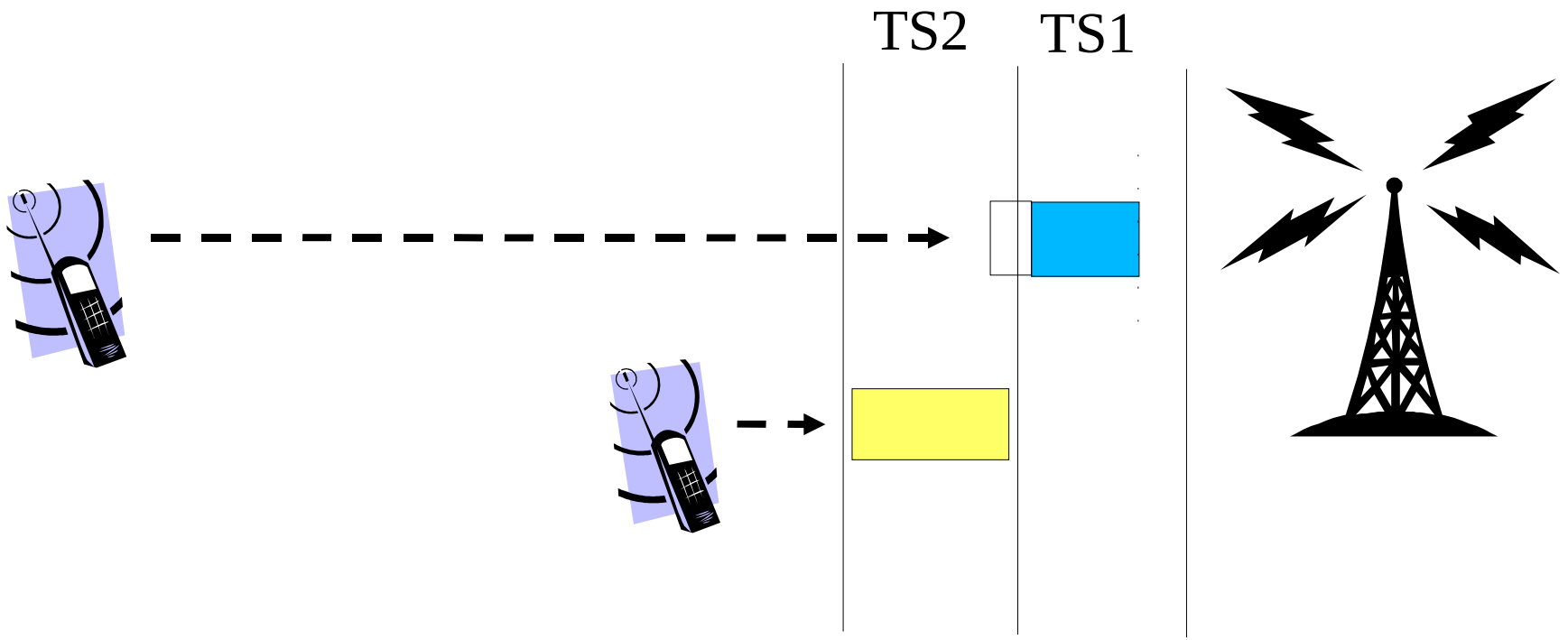
Access burst



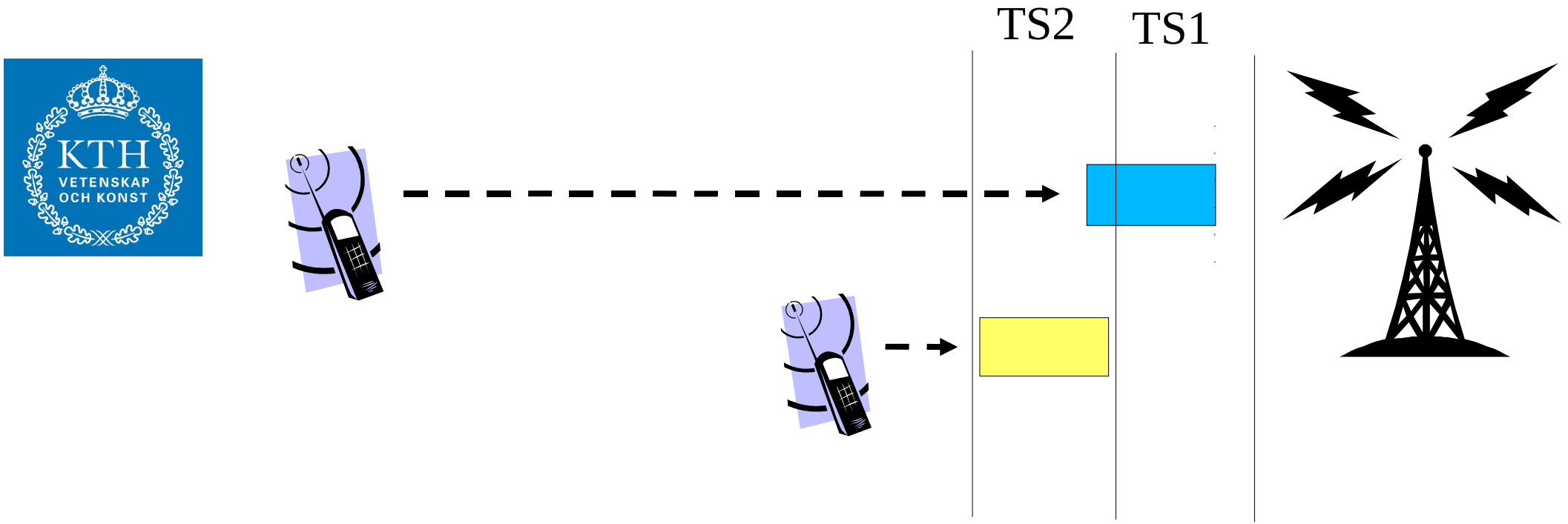
Access burst

- Made shorter to fit into a time slot even if the mobile is far a way (do the math, how many km is 68.24 bits).
- The data fields contains the address of the mobile doing the request.

Access burst



Adaptive frame synchronization



Timing advance

- When replying to a random access request the BSS will inform the MS of the *timing advance* to use.
- Timing advance is coded in six bits (0-63) and each step indicates one bit period earlier transmission.
- An idle mobile need not know its timing advance.
- A mobile that is connected need constant updating of the timing advance value.

Timing advance

- The extra guard of the access burst allows a phone to be aprx 35 km away from a BTS .
- Each bit duration is aprx equivalent to 500m.
- Timing advance is reported using the SACCH when a connection (SDCCH/TCH) is established.