• **FDMA with Channel Freq:** 200 kHz
• **TDMA:** 8 time slots per frequency carrier

• **Theoretical No. of carriers:** $25 \text{ MHz} / 200 \text{ kHz} = 125$
• **Theoretical Max no. of user channels** = $125 \times 8 = 1000$

• **Practical Considering guard bands** = $124 \times 8 = 992$ channels
Data burst, 156.25 bit periods = $\frac{15}{26} \text{ ms} = 577\mu\text{s}$
1. GSM frame structure assumes that all Mobile stations are synchronized with the same clock.

2. In practice, the BTS transmits a sync signal in the SCH channel (logical) which is used by all MS in the cell for timing.

3. Everything will work very well if all MS were located at the same distance from the BTS.

4. In practice MS can be anywhere from a few meters to 35 Kms from a base station.

5. The GSM system, must therefore take into account the propagation delay.

\[
\text{Bit Period} = \frac{577}{156} = 3.7 \, \mu s
\]

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>DELAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1km</td>
<td>( \frac{1 \times 10^3}{3 \times 10^8} = 3.3 \times 10^{-6} )</td>
</tr>
<tr>
<td>30km</td>
<td>( \frac{30 \times 10^3}{3 \times 10^8} = 100 \times 10^{-6} )</td>
</tr>
</tbody>
</table>
LOGICAL CHANNELS

**PCH**
- Paging Channel used by network to alert mobile for call from another calling mobile.

**FACCH**
- Fast Associated Control Channel is used to exchange information between MS and BTS faster than SACCH.

**TCH/FS**
- Traffic channel full rate speech digitized at 13kbps data rate. After channel coding is applied the rate becomes 22.8kbps.

**TCH/H**
- Carries half rate speech. Two half rate TCH channels use one physical channel.

**AGCH**
- Access Grant Channel carry information by which mobile will determine whether the access to the network has been granted.

**RACH**
- Random Access Channel is used by Mobile to access the GSM network during call set-up time.

**SACCH**
- Slow Associated Control Channel

**Note:** These logical channels (type of burst) are then mapped onto Physical channels.

A GSM Physical channel comprises a particular timeslot on a given freq. Channel.
1. Uplink and downlink are separated in frequency

2. Gap of 3 slots in uplink and downlink slots

So the MS does not have to Transmit and Receive at the same time instance!

(a) Mobile station TRX

(a) Base station TRX
GSM TDM requires that each user transmits periodically for less than one-eighth of the time within one of the eight timeslots.

Since the users are at various distances from the base station and radio waves travel at the finite speed of light, the precise arrival-time within the slot can be used by the base station to determine the distance to the mobile phone.

To prevent collisions, the time at which the phone is allowed to transmit a burst of traffic within a timeslot is adjusted accordingly to prevent collisions.

Timing Advance (TA) is the variable controlling this adjustment.

TA is used to compensate the propagation delay of transmission due to distance between BS and BTS.

WHAT IS TIMING ADVANCE?

<table>
<thead>
<tr>
<th>Distance</th>
<th>TA Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100m</td>
<td>Less TA</td>
</tr>
<tr>
<td>35km</td>
<td>More TA</td>
</tr>
</tbody>
</table>
R = 100m
Delay, \( d = \frac{2 \times 100}{3 \times 10^8} = 0.66 \mu sec \)

R = 35km
Delay, \( d = \frac{2 \times 35 \times 10^3}{3 \times 10^8} = 233 \mu sec \)
1. If the MS moves away from BTS during calling, the signal from BTS to MS will be delayed, so will the signal from MS to BTS.

2. If the delay is too long, the signal in one timeslot from MS cannot be correctly decoded, and this timeslot may even overlap with the timeslot of the next signal from other MS, leading to inter-timeslot interference.

3. Therefore, the report header carries the delay value measured by MS.

4. BTS monitors the arrive time of call and send command to MS every 480 ms, prompting MS to use a specified timing advance (TA) value.
TIME ADVANCE ZONES

Distance between TA zones

\[ d = \frac{35 \times 10^3}{64} = 547 \text{m} \]
MS advances its burst transmission by a time corresponding to round trip time.

• The delay is quantified as a 6 bit number.
  => 64 steps (0-63); each step advances the Timing by one bit duration
  i.e 577/156 = 3.7 μs.

• 64 steps allows compensation over a maximum propagation
  time of 3.7x64 = 31.5 bit periods or 3.7 X 31.5 = 113.5 μs ( => a maximum distance
  of ~ 35 km)

\[ d = 3 \times 10^8 \times 113.5 \times 10^{-6} = 34 \times 10^3 \text{ m} \]
Timing Advance: How it works.

-One way Propagation delay
-Two way propagation delay

(Sent by BS on down link)

(received by BS on up link)

(received by MS on down link)

(Sent by MS on up link)
MAXIMUM RANGE OF GSM MOBILE STATION

1. GSM uses 6-bits to represent Timing Advance (TA).

2. TA value is therefore limited to the range 0 to $2^6-1$, i.e 0 - 63 or (0 -233μs).

3. Therefore, the maximum coverage distance of the GSM is calculation is as follows:

$$ R = \frac{1}{2} (t_b \ N_b \ c) $$

where

- $t_b = 3.7 \ \mu s/\text{bit}$ is the duration per bit
- $1/(270.833\times10^3)$
- $N_b = 63\text{bit}$ is the maximum bit for time coordination (guard band)
- $c$ is the speed of light

Substituting we get

$$ R = \frac{1}{2} (3.7 \times 10^{-6} \times 63 \times 3 \times 10^8) = 35 \text{ kms} $$
METHOD 2 - PROPAGATION DELAY(1)

• If an access burst has a guard period of 68.25 bits this results in a maximum delay time of approximately 252µs (3.69µs × 68.25 bits).

• This means that a signal from the MS could arrive up to 252µs after it is expected and it would not interfere with the next time slot.
The next step is to calculate how far away a mobile station would have to be for a radio wave to take 252µs to arrive at the BTS.

\[ R = c \times t = 3 \times 10^8 \times 252 \times 10^{-6} = 75.6 \text{ km} \]

But we must take into account that the MS synchronizes with the signal it receives from the BTS.

We must account for the time it takes for the synchronization signal to travel from the BTS to the MS.
METHOD 2 - PROPAGATION DELAY (3)

Sych burst 252µs

Access burst 252µs

37.8 km

Acceptable delay = 252/2 = 126 µs
INCREASING GSM RANGE

• Sometimes a greater coverage area is required, such as in coastal areas.
• Then, the number of channels that each TRX contains must be reduced in the extended cell.
• The method is to bind odd and even timeslots, so there are only four channels (0/1, 2/3, 4/5, and 6/7) for each TDMA frame in extended cell.
**GSM UPLINK & DOWNLINK TIME SLOT SEQUENCE**

**Downlink**
MS receives data on time slot 2

**Uplink**
MS transmits data on time slot 2 with appropriate timing advance
**GSM NORMAL BURST**

**Training sequence**
26 bit sequence used by the receiver’s equalizer to estimate the transfer characteristic of the physical path between the BTS and the MS.

**Guard Period**
Timeslot is 0.577 ms long, whereas the burst is only 0.546 ms long. A guard period of 0.031 ms is provided.

**Stealing flags**
Set when a traffic channel burst has been “stolen” by a FACCH.

**INFO**
Fields holding data or control information

**Trail bits**
Used to indicate the beginning and end of the burst.
**Normal burst**
Carries traffic channels and all types of control channels.

**Frequency Correction Burst**
carries FCCH downlink to correct the frequency of the MS’s local oscillator, locking it to that of the BTS.

**Synchronization Burst**
Used for synchronizing the timing of the MS to that of the BTS.

**Dummy Burst**
Used when there is no information to be carried on the unused timeslots of the BCCH Carrier (downlink only).

**Access Burst**
Used by the MS when BTS does not know the location of the MS and therefore the timing of the message from the MS is unknown. (uplink only.)