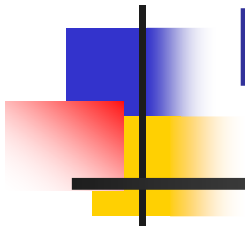

EC 551
Telecommunication System Engineering

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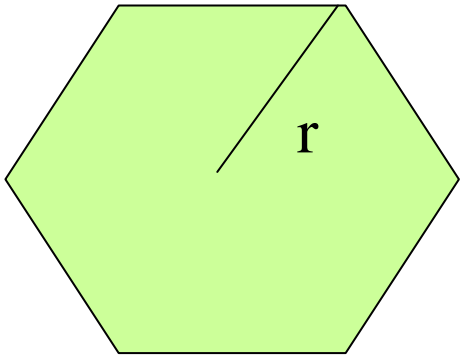
Syllabus

- Tentatively

Week 1	Overview
Week 2	**Wireless Channel characteristics**
Week 3	**OFDM and modulation techniques**
Week 4	Coding techniques in wireless systems
Week 5	**WiMax**
Week 6	**WiMax Physical Layer**
Week 7	WLAN Physical Layer
Week 8	WLAN MAC Layer
Week 9	**Cellular Communication Concept**
Week 10	FDMA, TDMA, CDMA and Duplexing
Week 11	**GSM System**
Week 12	GPRS System
Week 13	UMTS
Week 14	IP networks
Week 15	VOIP

Compute total system capacity

- Example
  - Total coverage area = 100 mile^2 = 262.4 km^2
  - Total 1000, 1256 duplex channels
  - Cell radius = 1km , 0.5km
  - N=4 or N=7
- What's the total system capacity for N=4 and N=7?



$$A = \frac{3\sqrt{3}}{2} r^2 = 2.6 r^2$$

Compute total system capacity

- # of cells = 262.4/2.6=100 cells
- # of usable duplex channels/cell
  - S=(# of channels)/(reuse factor)
  - S_4=1000/4=250
  - S_7=1000/7=142
- Total system capacity (# of users could be accommodated simultaneously)
  - C=S*(# of cells)
  - C_4=250*100=25000
  - C_7=142*100=14200

Cellular concepts

- W – total available spectrum, B – bandwidth per user, N is the frequency reuse factor, m – number of cells, number of simultaneous users is given by **n = (m/B)*(W/N)**
- # of users can be increased by
  - Increasing m (cells)
  - Decreasing cluster size (N)
- A small cell size
  - Results in longer battery life
  - Reduces handset size
  - Increases handoffs
  - Increases signaling load
  - Increases the complexity of design and network deployment

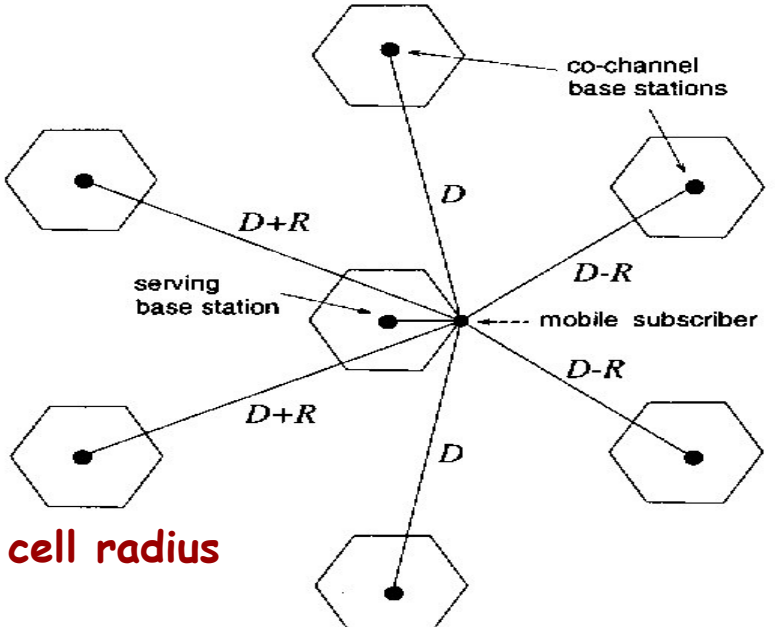
Worst-Case CCI on the Forward Channel

- Co channel interference [CCI] is one of the prime limitations on system capacity. We use the propagation model to calculate CCI.

- There are six first-tier, co-channel BSs, two each at (approximate) distances of D-R, D, and R+D and the worst case (average) Carrier-to-(Co-Channel) Interference [CCI] is

$$\Lambda = \frac{1}{2}\frac{R^{-\beta}}{(D-R)^{-\beta} + D^{-\beta} + (D+R)^{-\beta}}$$

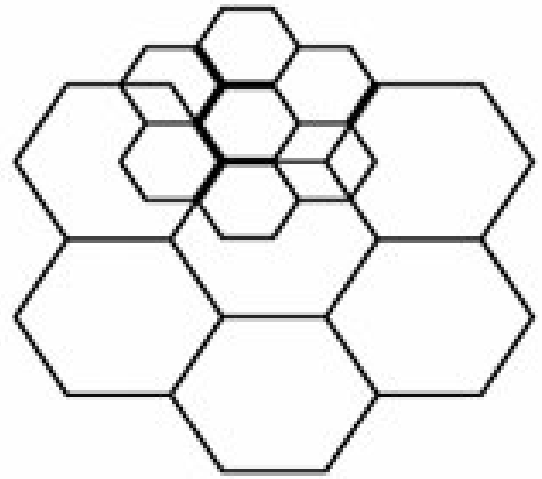
Worst case CCI on the forward channel



R= cell radius

Cell splitting

- Smaller cells have greater system capacity
  - Better spatial reuse
- As traffic load grows, larger cells could split into smaller cells



Cell splitting is the technique of splitting a congested cell into smaller cells.

- ➔ New (smaller cells) have their own base stations with reduced antenna height and reduced power.
- ➔ Cell splitting increases capacity since frequency reuse can be increased.
- ➔ Cell splitting preserves the geometry of the architecture and therefore simply scales the geometry of the architecture.
- ➔ In the following figure the cell radius has been reduced by half.

the simple propagation model

$$P_R = P_o \left(\frac{d}{d_o} \right)^{-n}$$

At the cell boundary the distance d is R, the unsplit cell radius. Consider both an unsplit and a split scenario. For the unsplit case

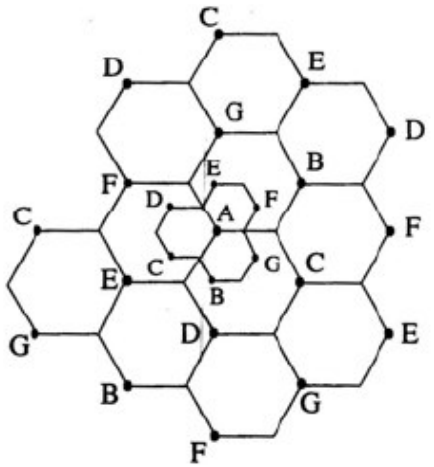
$$P_{r(unsplit)} = P_{t,unsplit} R^{-n}$$

For the split case

$$P_{r(split)} = P_{t,split} \left(\frac{R}{2} \right)^{-n}$$

or

$$P_{r,split} = P_{t,split} R^{-n} 2^n$$



For the received signal powers to be equal we must have

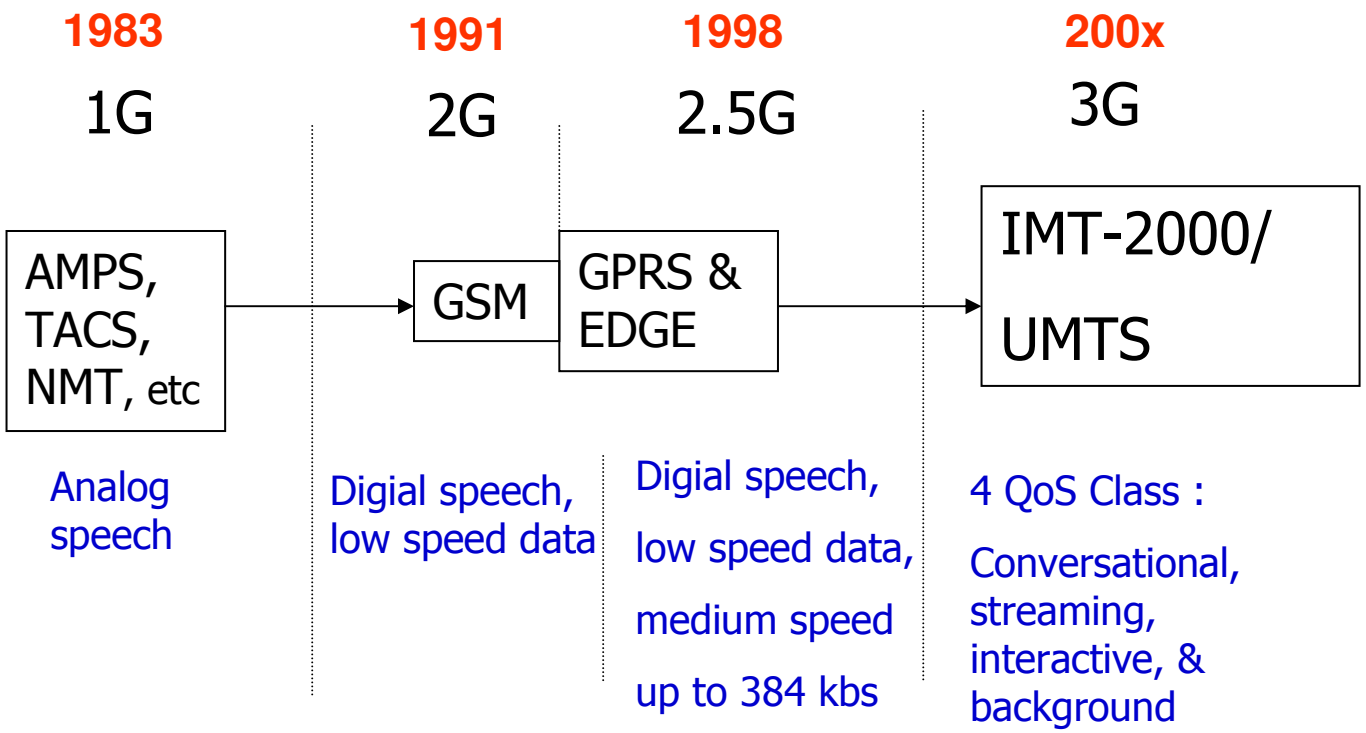
$$P_{t,unsplit} R^{-n} = P_{t,split} R^{-n} 2^{n}$$

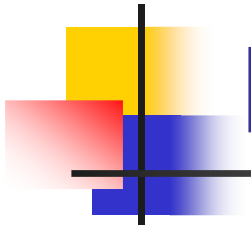
The ratio of transmitted powers is important. Consider the following:

$$\frac{P_{t,split}}{P_{t,unsplit}} = 2^{-n}$$

Note the role of the path loss exponent. For $n = 4$, the transmitted can be reduced by a factor of 16 and still provide equal received signal powers.

A Little Piece of History





Elements of the Network

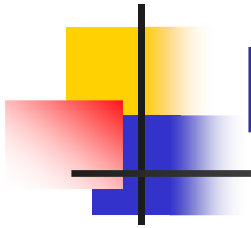
- Subscriber: user who pays subscription charges for using mobile communication services.
- Mobile Station: is a subscriber unit intended for use while on the move at unspecified locations. It could be a hand-held or a portable terminal.
- Base Station: a fixed radio station used for communication with MS. It is located at the centre of a cell and consist of Transmitters and Receivers.
- Mobile Switching Centre : it coordinates the routing of calls, do the billing, etc.

Mobile Station

- **MS consist of :**
  - **Mobile Equipment (ME)**
  - **Subscriber Identification Module (SIM)**

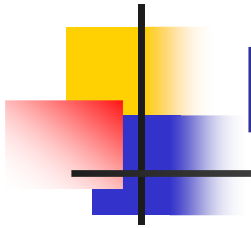
SIM Card

- **Subscriber Identity Module (SIM) is a smart card which stores information about the subscription and feature of services.**
- **Stored information including:**
  - **Authentication Key "Ki"**
  - **Encryption**
  - **IMSI and TMSI**
- **SIM card is protected by a Personal Identity Number (PIN) of the user**



Base Station Subsystem

- BTS: Base Transceiver station
  - 3 Antennas: 2 Rx & 1 Tx.
  - Microwave link with the network
- BSC: Base station controller
  - Control many (BTS)
  - It handles many functions:
    - Channel Allocation
    - Link quality Supervision



Base Station Subsystem

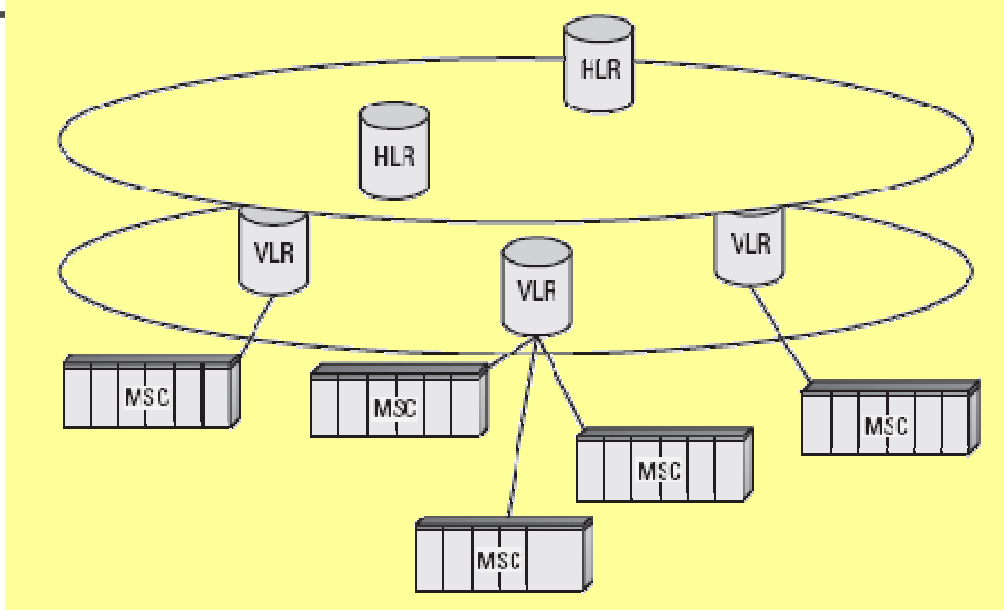
- Transmission of broadcast messages
- Controlling power level
- Controlling frequency hopping
- Error correction coding and decoding
- Hardware processing
- Data and signaling encryption
- Digital speech transcoding
- Data rate adaptation

Base Transceiver Station (BTS)

- BSC control RRM for BTSs.
- BSC handle radio-channel setup, frequency hopping, and handover within BSC

- **BSS consist of two part :**
  - **Base Transceiver Station (BTS)**
  - **Base Station Controller (BSC)**
- **BTS is a radio-end which determine a cell coverage and provide link with MS.**
- **BTS include Transmitters and Receivers, antenna and signal processing unit as well as interface.**
- **BTS communicate with MS via air interface**

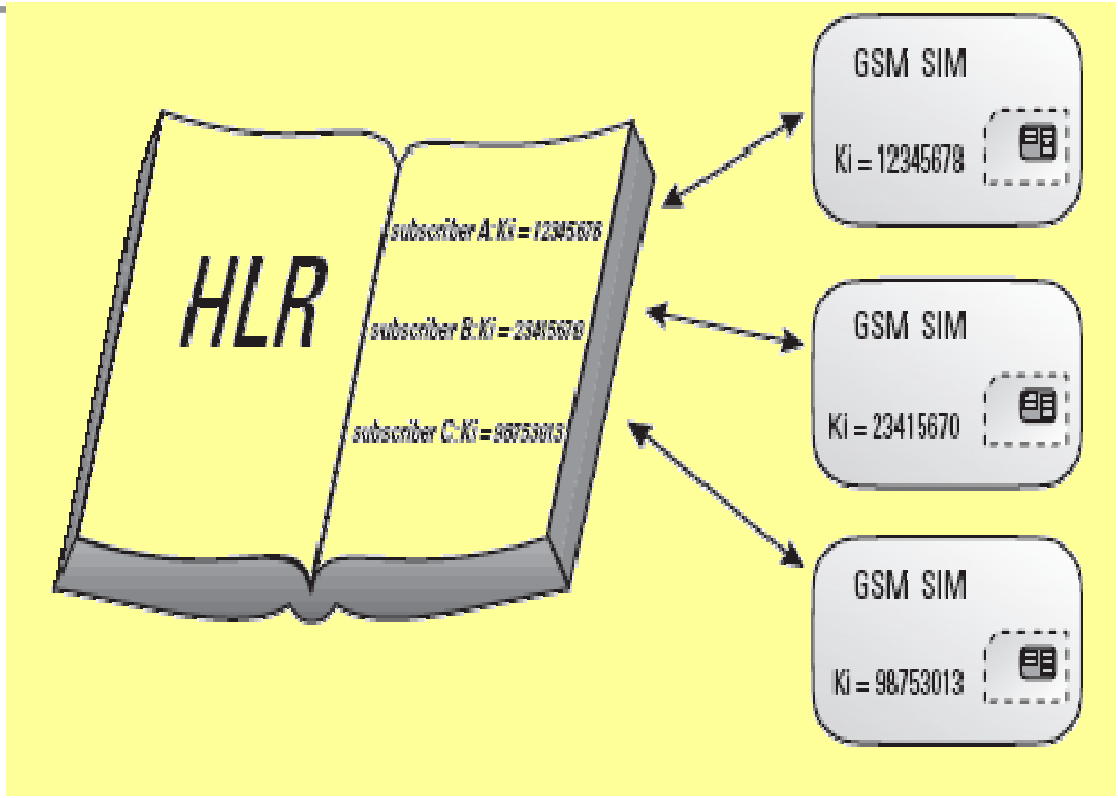
Mobile Switching Center (MSC)



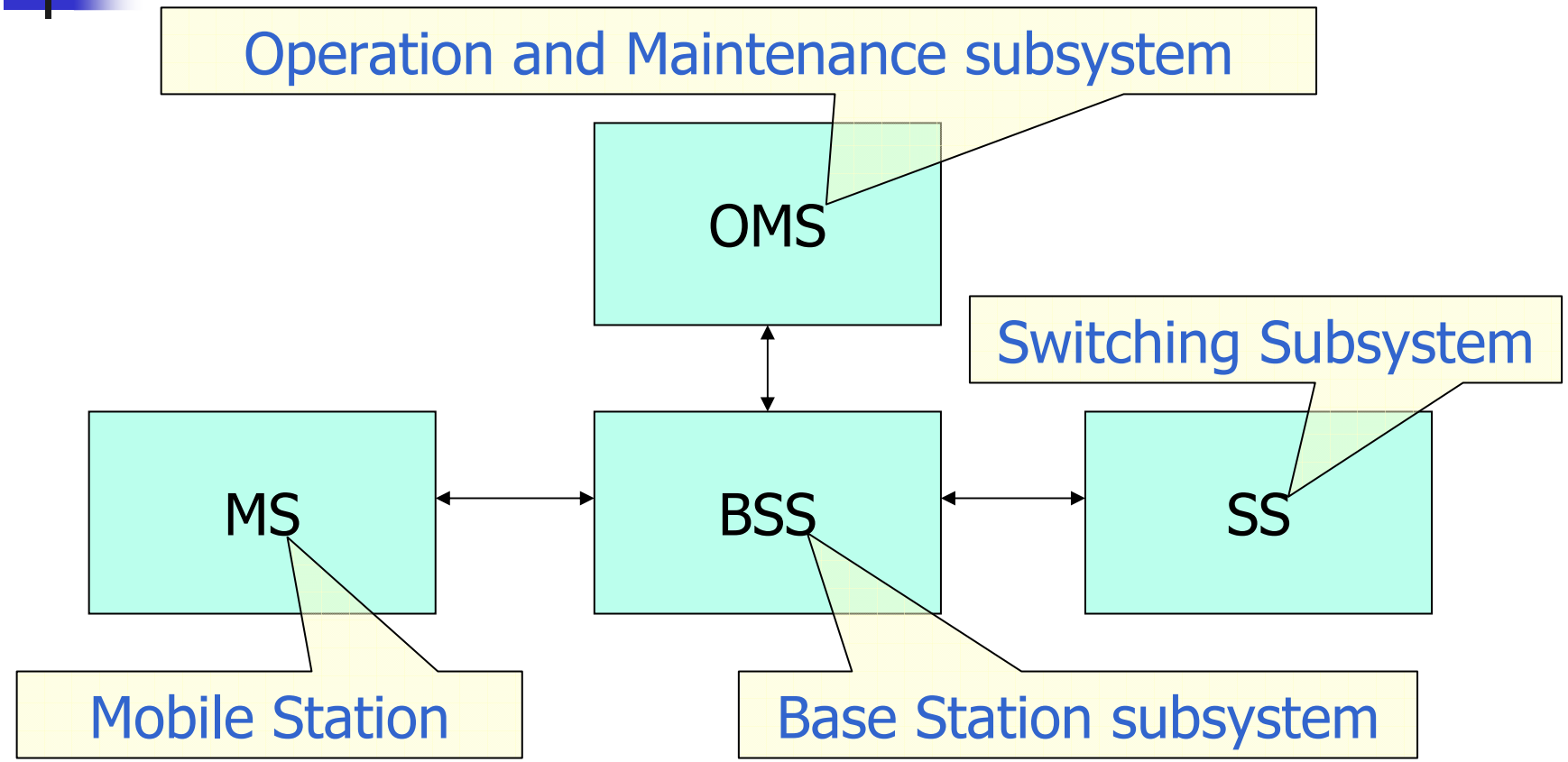
- **As a central switch for routing the traffic**
- **Control BSC via A-interface**
- **As a interconnection between GSM network with other Networks via Internetworking Function (IWF)**

Home Location Register (HLR)

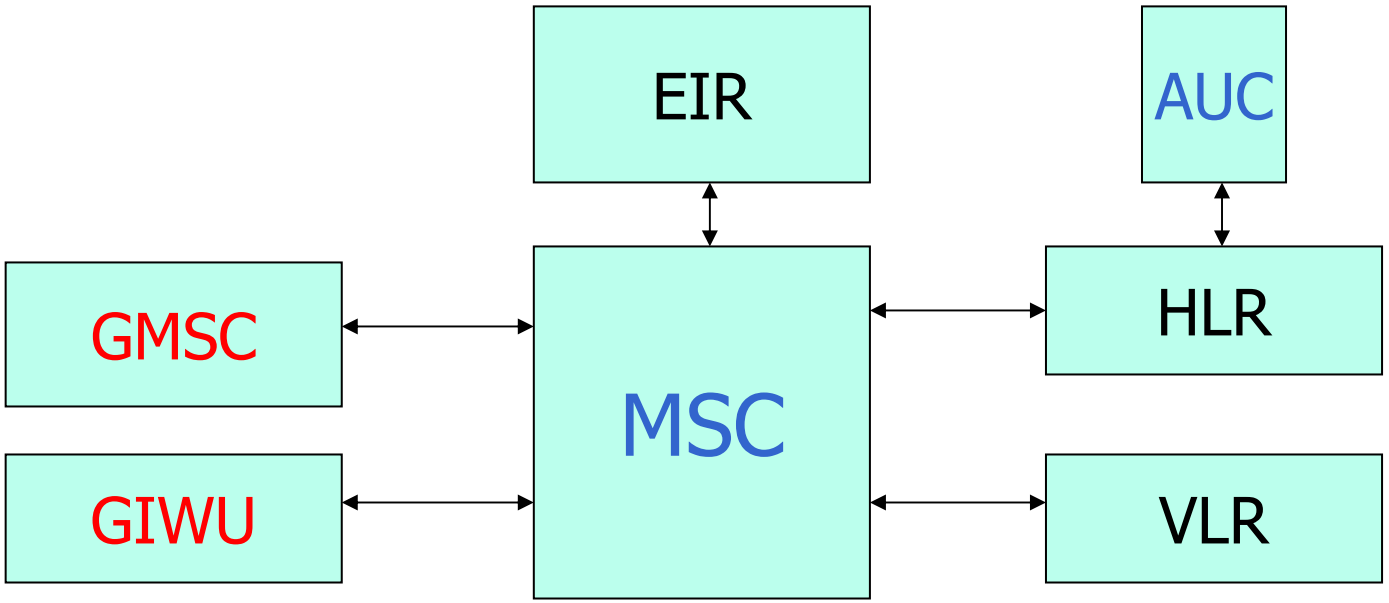
- HLR contain database of users, including all the subscription records
- HLR records the update location of every user for mobility management purposes



GSM Architecture



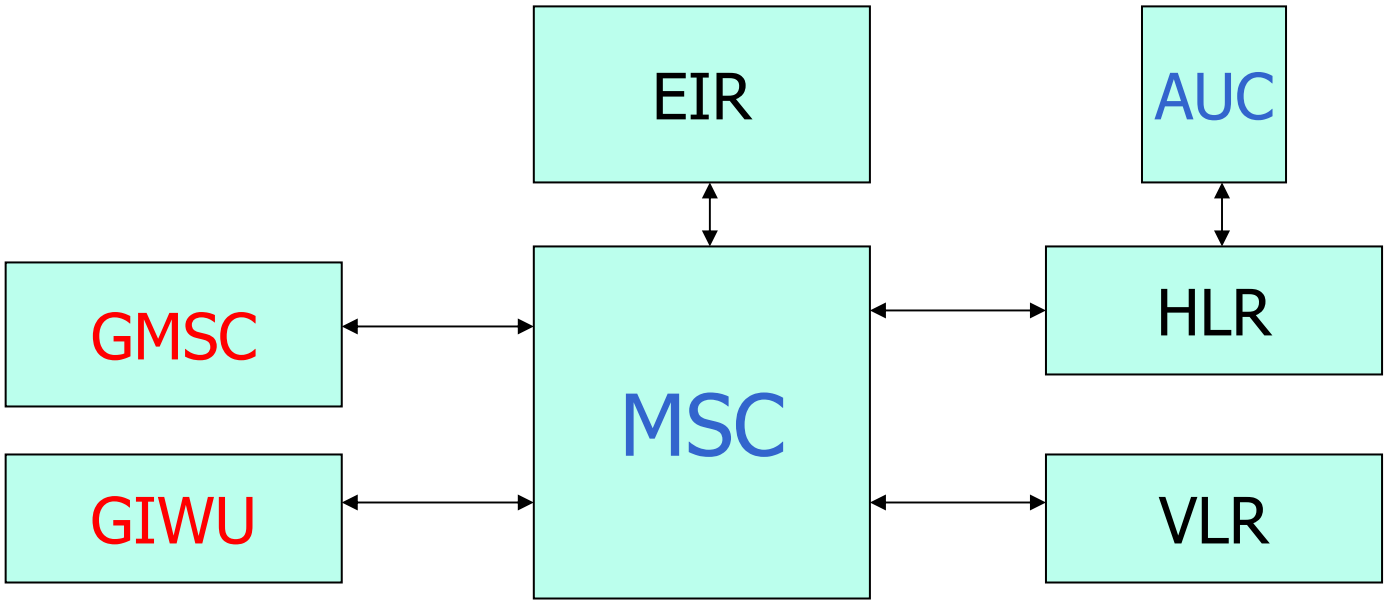
Switching Subsystem



MSC:Mobile Service Switching center

- Co-ordinates call setup
- One MSC control several BSC

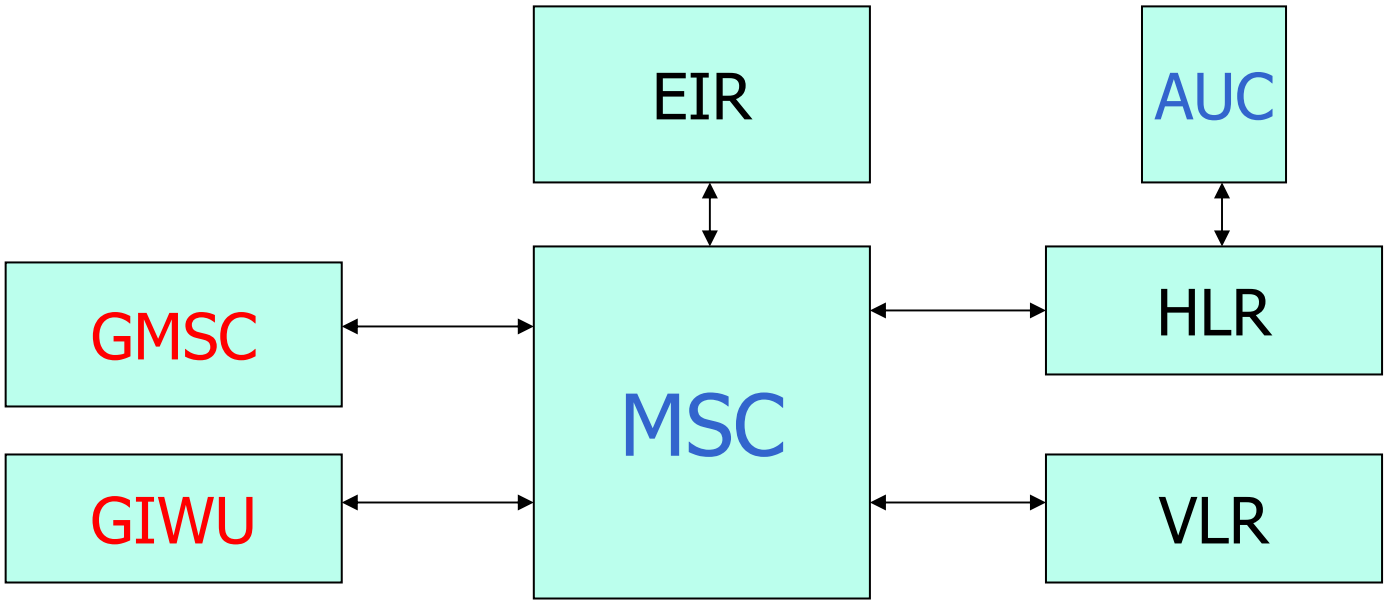
Switching Subsystem



HLR:Home Location Register

- Database of all subscribers information

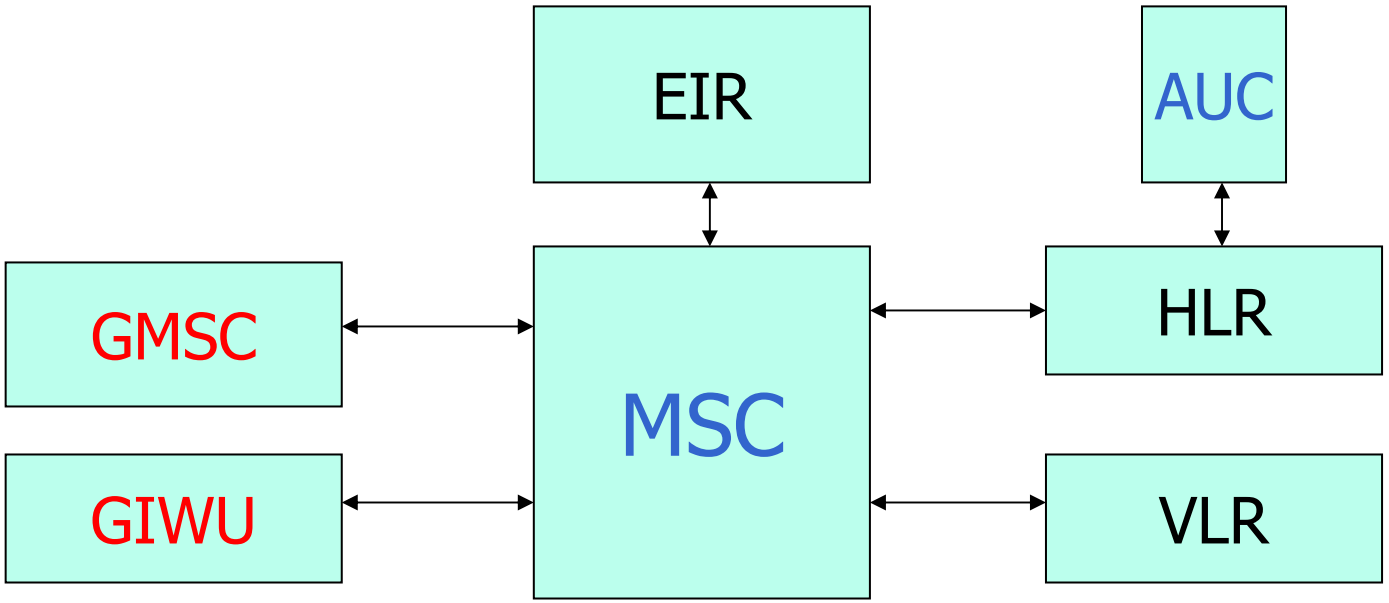
Switching Subsystem



AUC:Authentication center

- Manage the security data for subscriber authentication

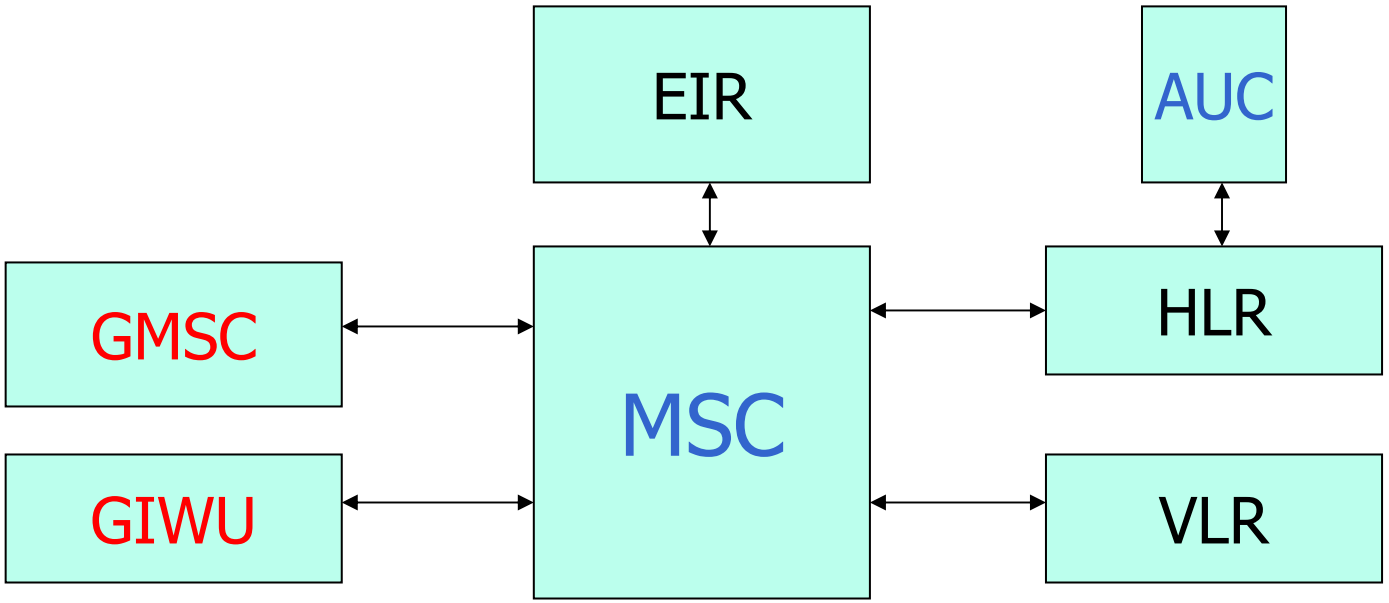
Switching Subsystem



EIR:Equipment Identity Register

- Database of all Mobile Equipments

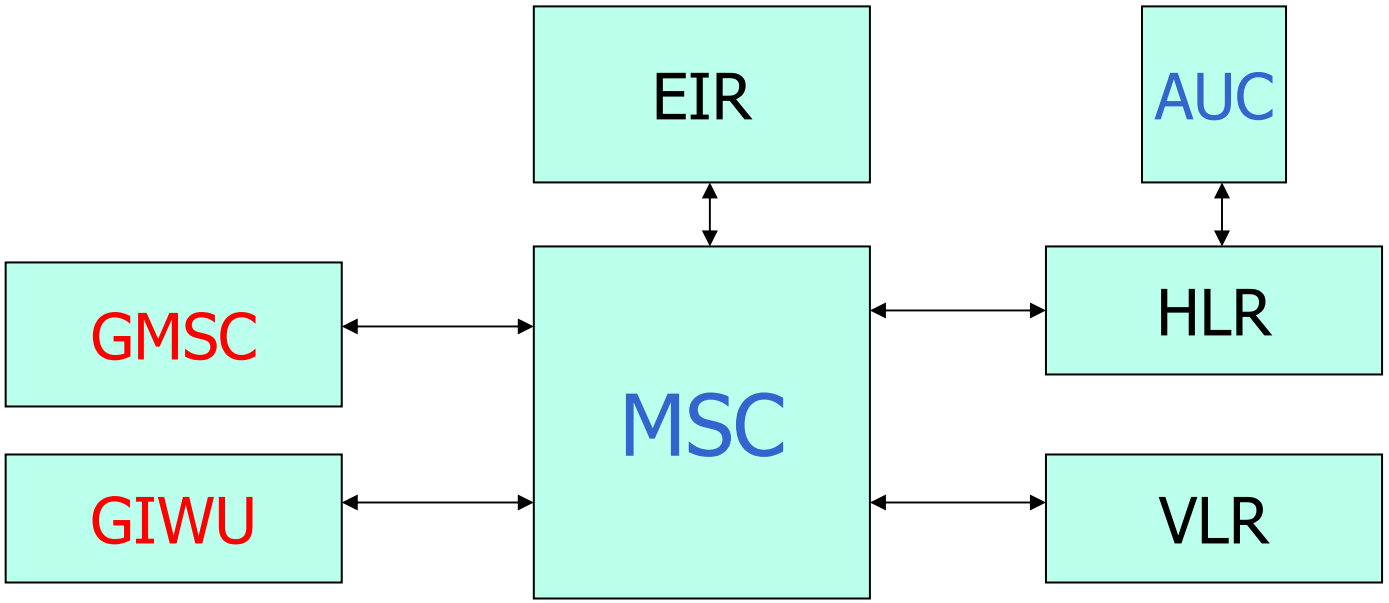
Switching Subsystem



VLR:Home Location Register

- Database of all visitors information

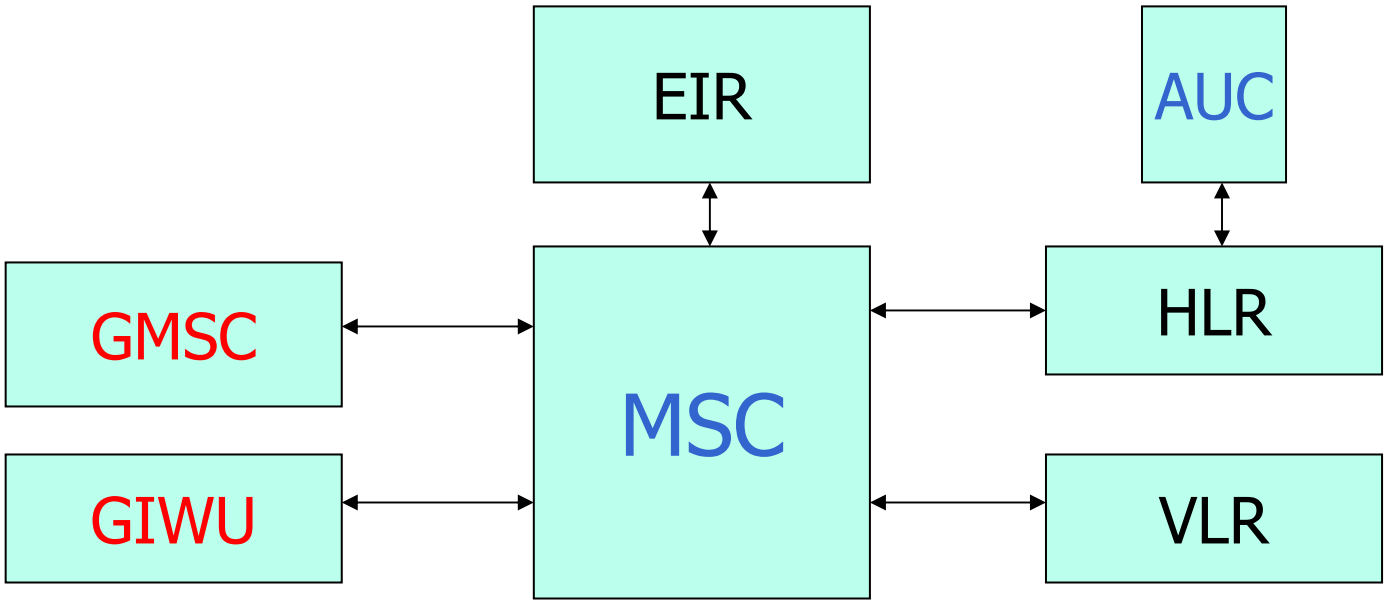
Switching Subsystem



GMSC:Gateway MSC

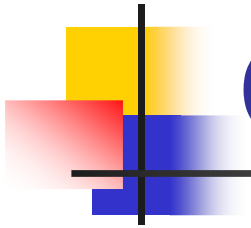
- Gateway to the PSTN

Switching Subsystem



GIWU:Gateway Networking Unit

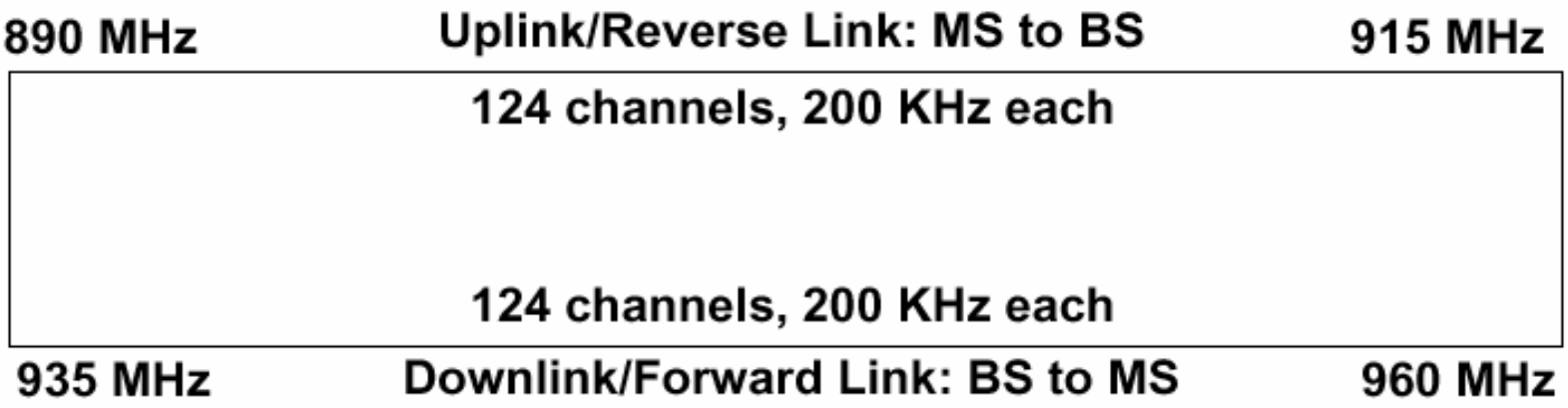
- For Communication with users outside GSM



OMS

- Operation and Maintenance Subsystem:
  - Network operation and maintenance
  - Subscription management: charging and billing.
  - Mobile equipment management

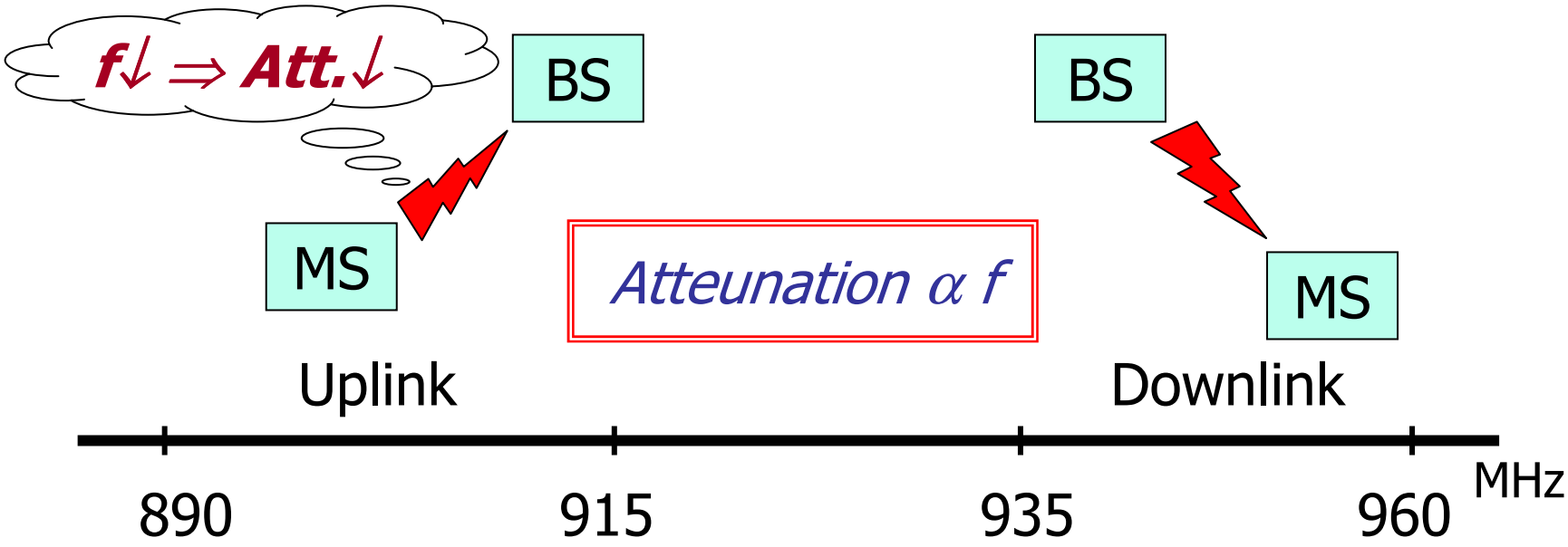
Spectrum Sharing



124 Traffic Channels x 8 Slots/Ch = 992 simultaneous conversations

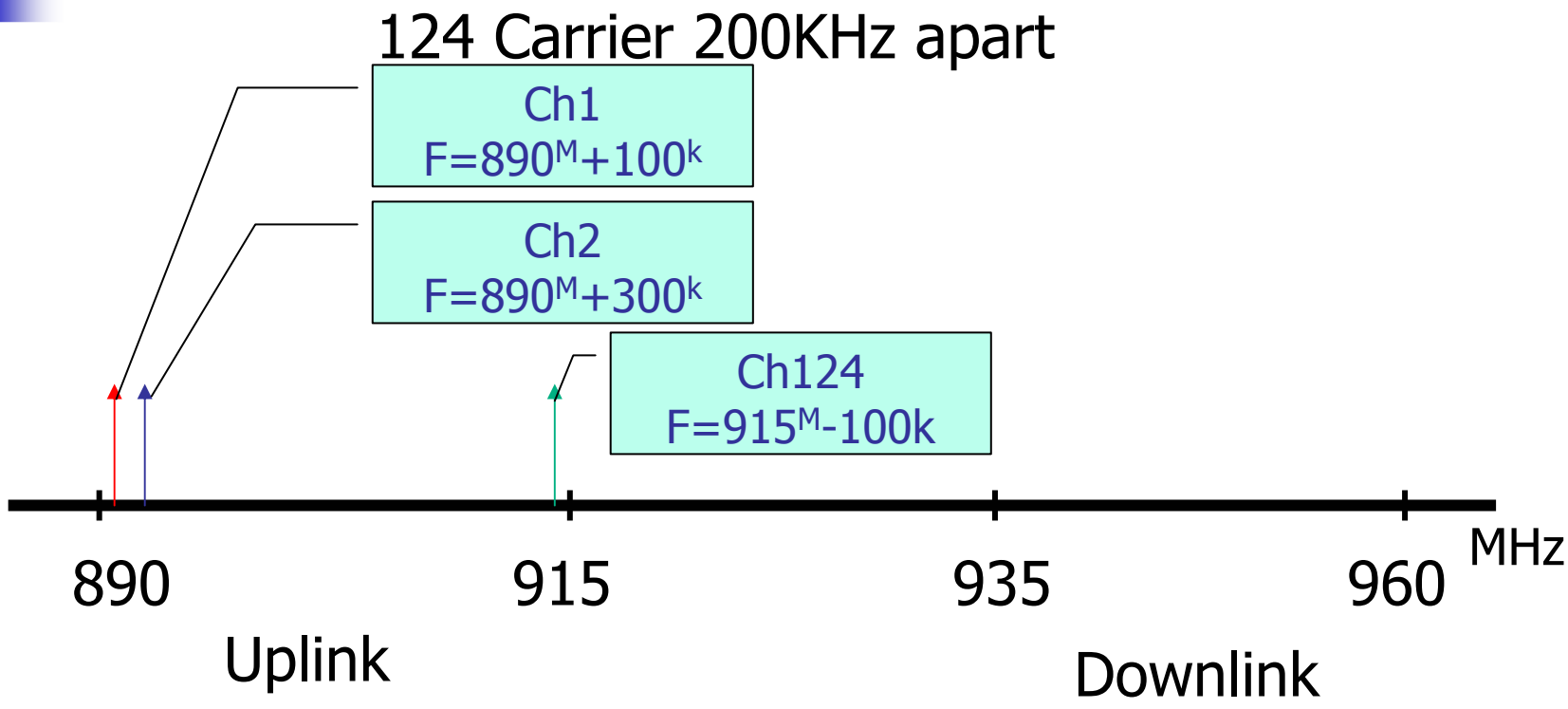
13 kbps speech coding data rate
9.6 kbps data rate
half rate coders being developed

FDD

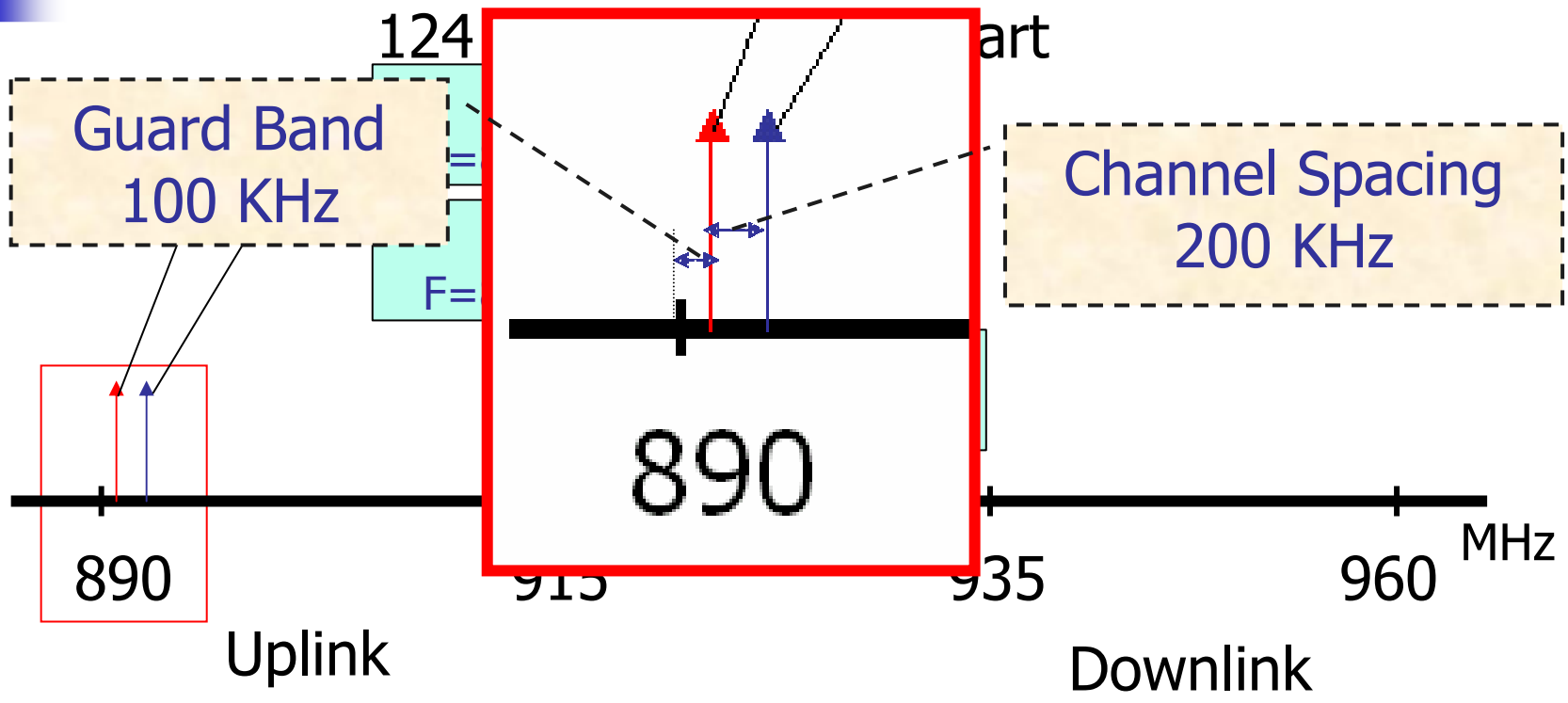


Total Band=25 MHz

FDM

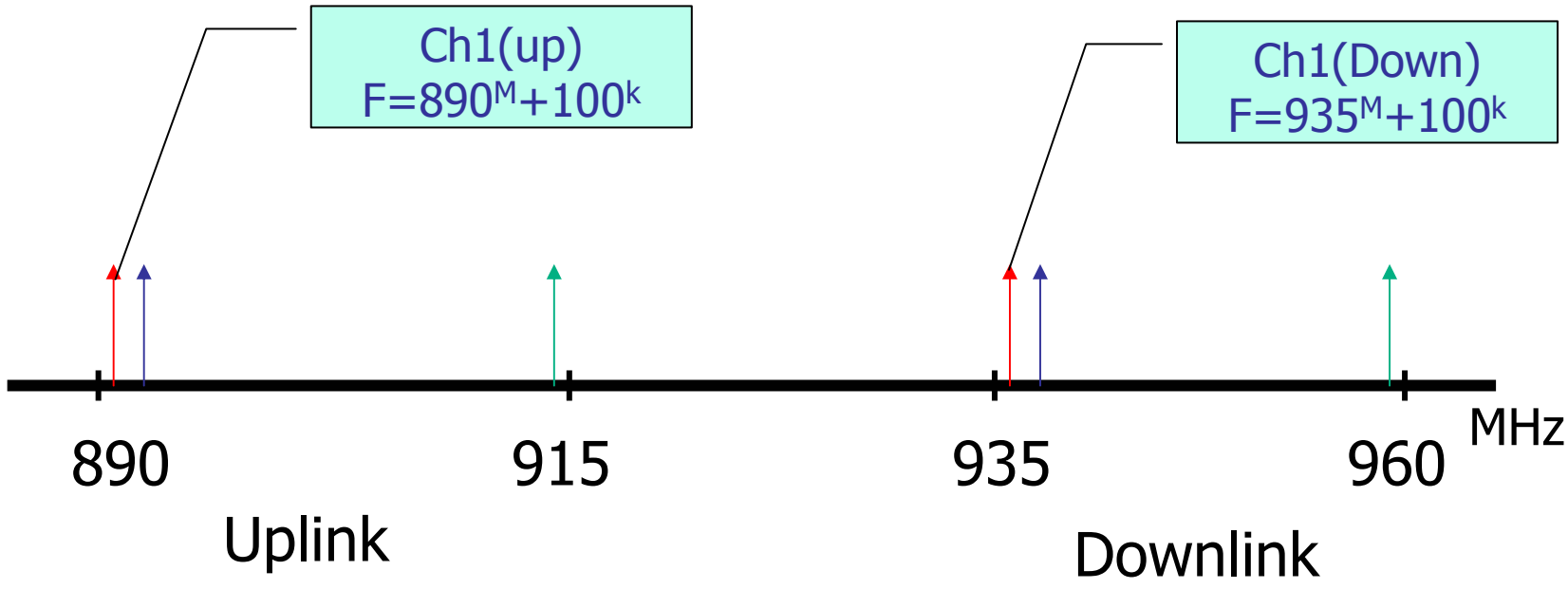

124 Carrier 200KHz apart
Ch1
F=890M+100k
Ch2
F=890M+300k
Ch124
F=915M-100k
890
915
935
960
MHz
Uplink
Downlink

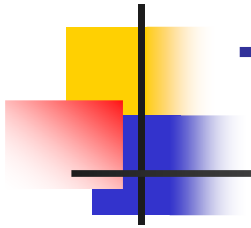
FDM


124
art
Guard Band
100 KHz
Channel Spacing
200 KHz
F=
890
890
915
935
960
MHz
Uplink
Downlink

FDM

124 Carrier 200KHz apart

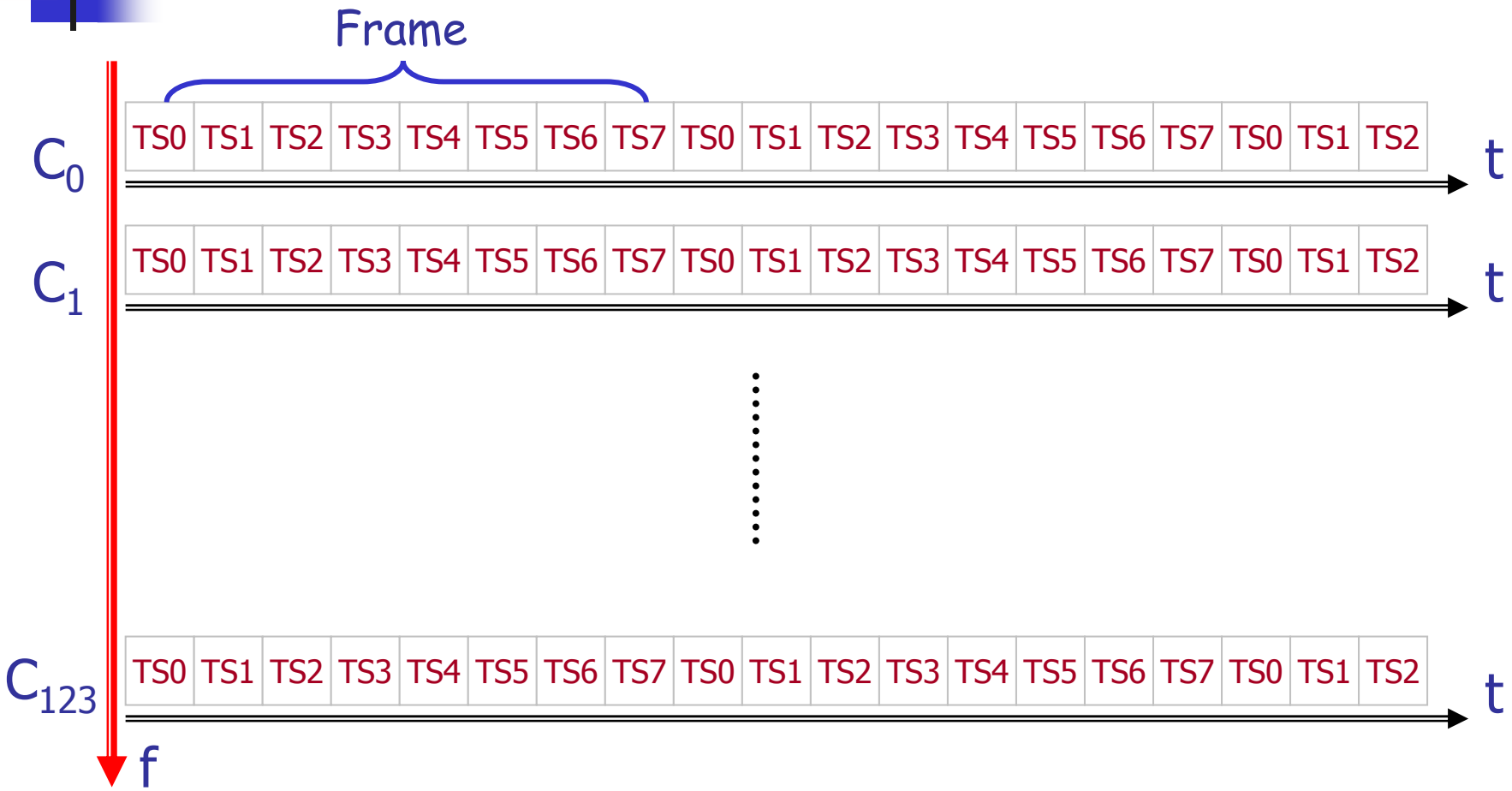




TDMA

- Every channel is shared among 8 users
- There are 124 Carriers each shared among 8 users.
- A User is assigned a certain time slot on a certain carrier (C_n,TS_k)

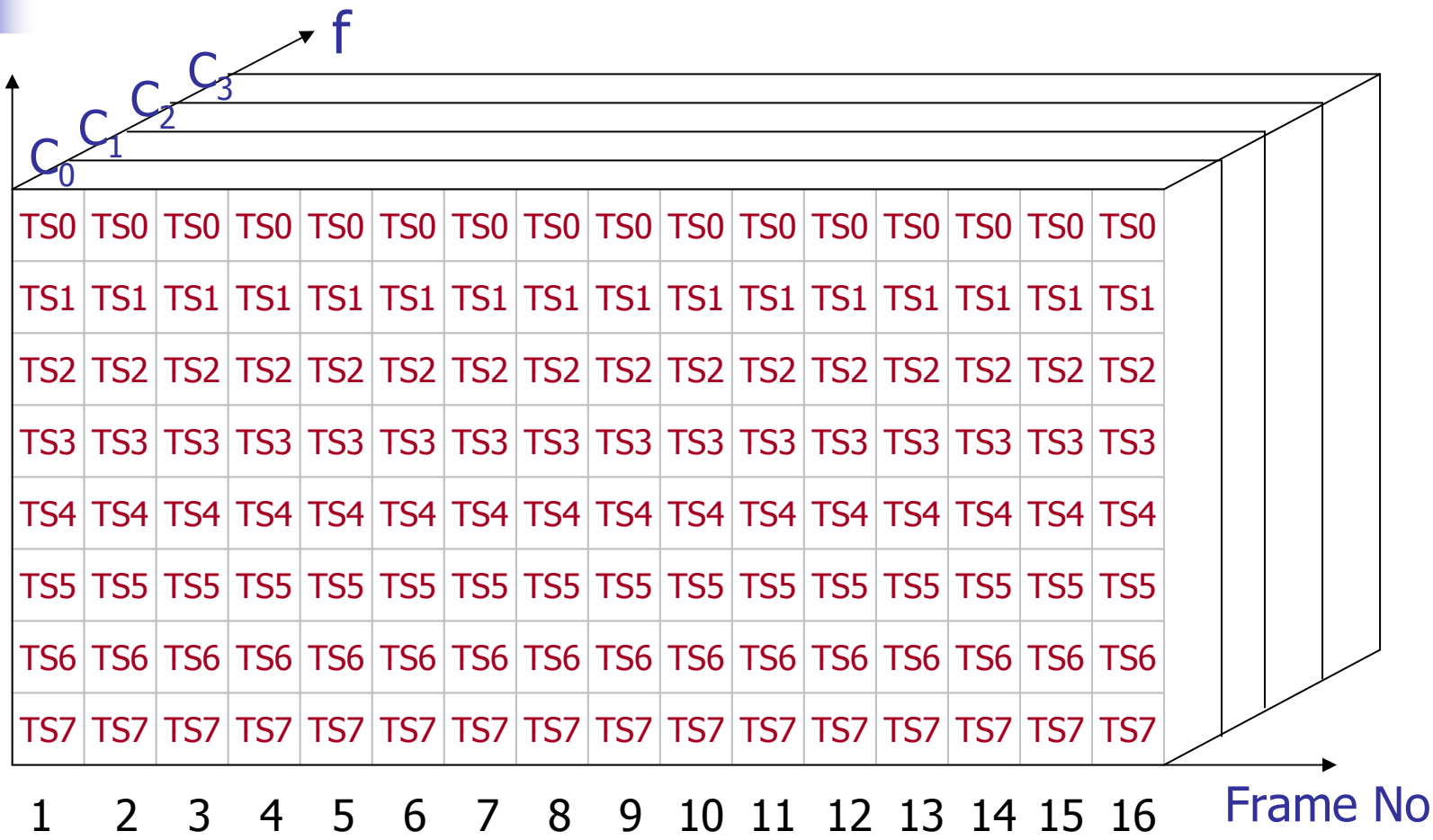
(C_n, TS_k)

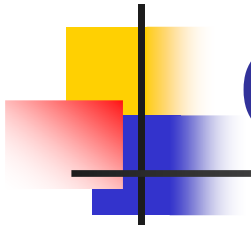

Frame
C0
C1
C123
TS0 TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS0 TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS0 TS1 TS2
t
f

(C_n, TS_k)

(C_{12}, TS_2)

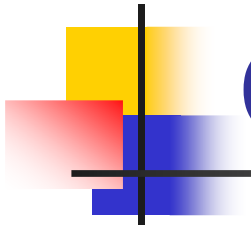
Channels Space (Copy Right)





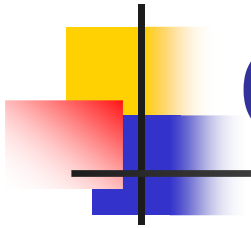
Channels

- Physical Channel:
  - It's a time slot on any carrier (C_n,TS_k).
- Logical Channel:
  - It's a channel mapped on a physical channel to do a certain job



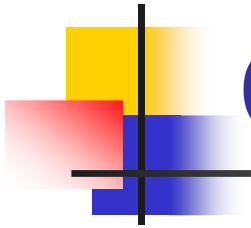
Channel Types

- Traffic Channels (TCH)
  - Used after call setup for transmission of speech.
- Control Channels (CCH)
  - Over head channels used for network administration and SMS.



Control Channels

- Broadcast Channels
- Common Control Channels
- Dedicated Channels



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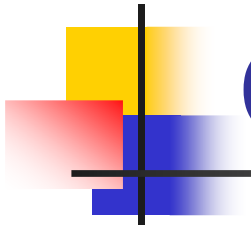
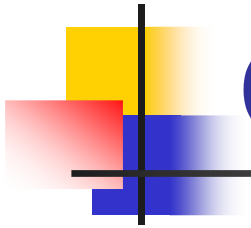


Control Channels

- Broadcast Channels
  - (FCCH): Frequency Correction Channel
    - No Data just pure carrier
  - (SCH): Synchronization Channel
    - Broadcast Mobile Network Identity Code
    - Broadcast Base Station Identity Code
    - Broadcast Current frame number
  - (BCCH): Broadcast Control Channel
    - Broadcast location area Identity
    - Broadcast maximum output power
    - Broadcast C_0 of neighboring cells



Control Channels

- Broadcast Channels
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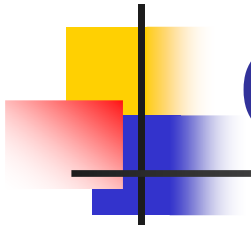
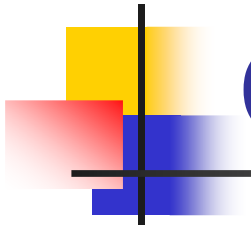


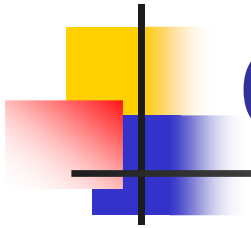
Control Channels

- Common Control Channels
  - (PCH): Paging Control Channel
    - Declare a coming call
  - (RACH): Random Access Channel
    - Used to initiate a call
    - Used to respond to a paging
  - (AGCH): Access Grant Channel
    - Used to assign a dedicated channel for further communication



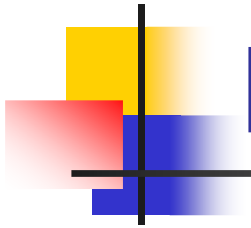
Control Channels

- Broadcast Channels
- Common Control Channels
- Dedicated Channels



Control Channels

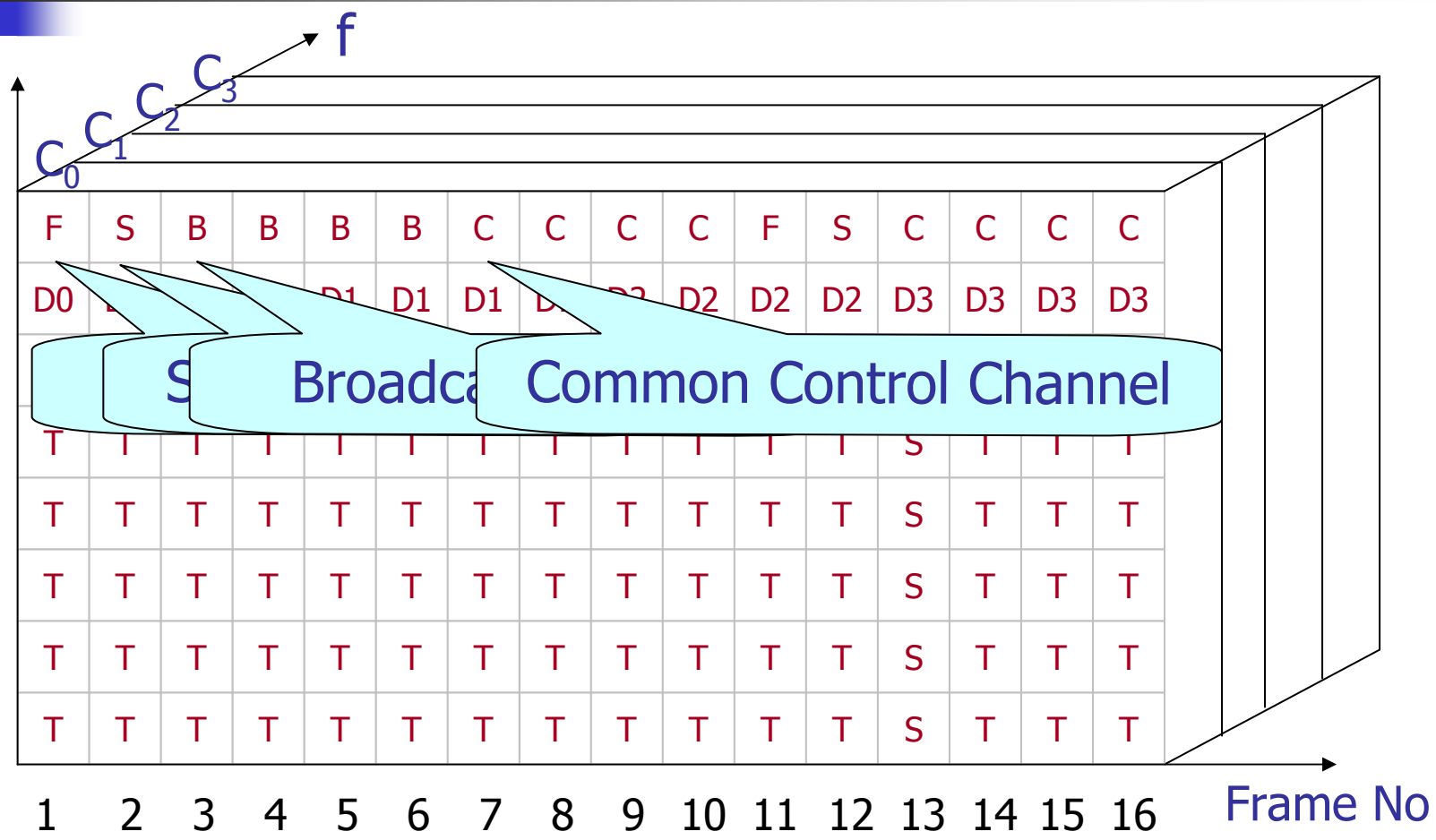
- Dedicated Channels
  - (SDCCH): Stand alone dedicated control Channel
    - Call setup procedure
    - SMS
  - (SACCH): Slow Associated control Channel
    - (↓) Setup power level and time advance
    - (↑) Inform the BS about received power level
  - (FACCH): Fast Associated control Channel
    - Stolen for urgent hardover



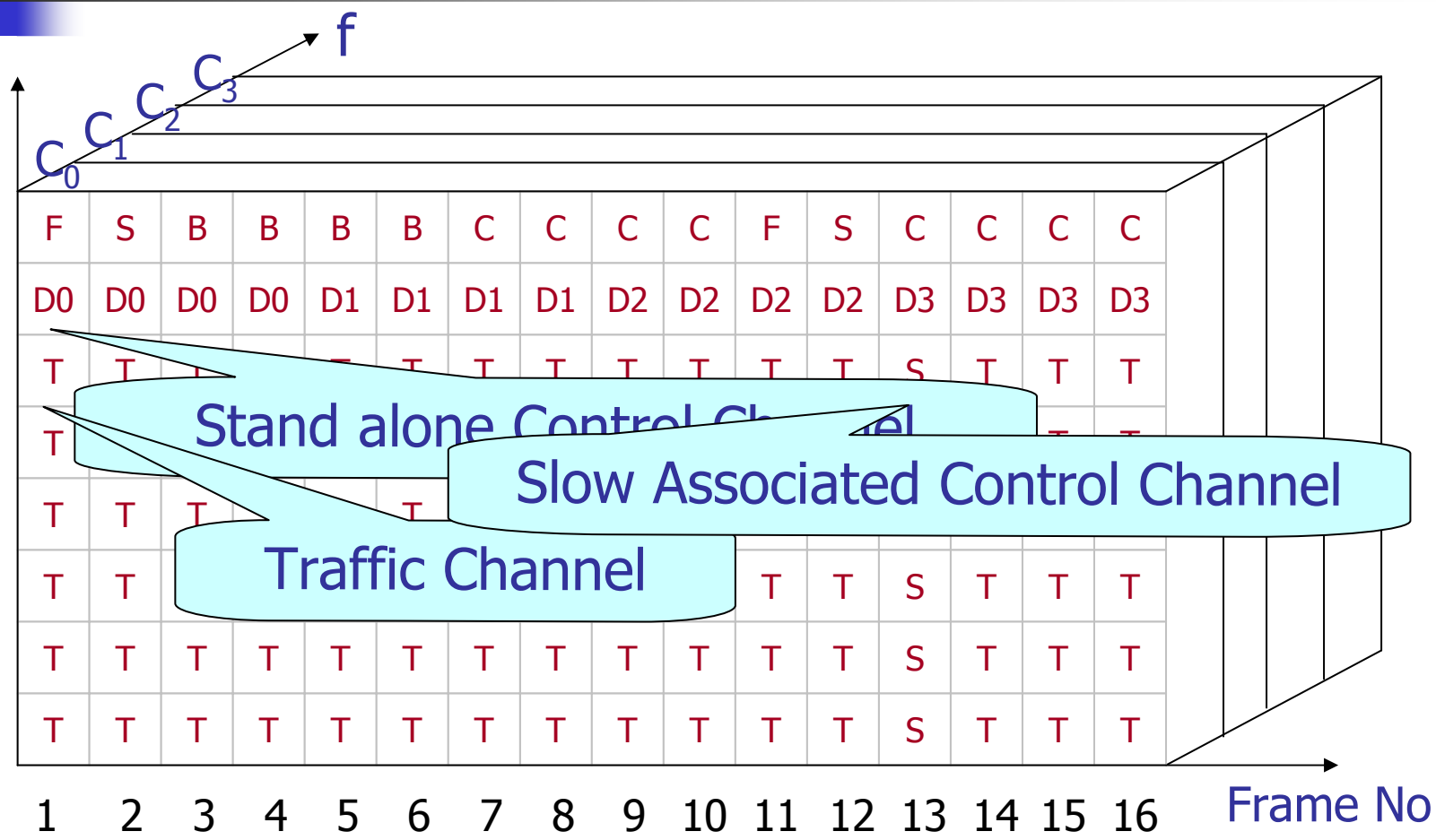
Burst

- It’s the information contained in one time slot
- 1 time slot = 0.577 m.sec.
- I frame = 8 time slots = 4.615 m.sec.

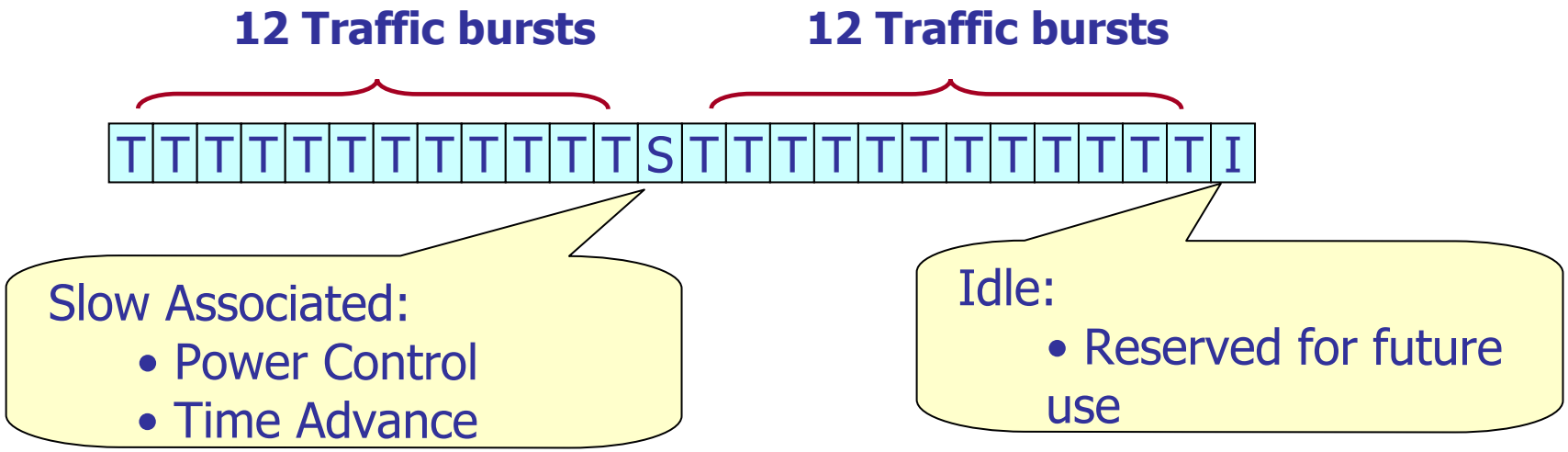
Mapping


f
C0
C1
C2
C3
F S B B B B C C C C F S C C C C
D0 D1 D1 D1 D2 D2 D2 D2 D3 D3 D3 D3
Broadca
Common Control Channel
T T T T T T T T T T T T S T T T
T T T T T T T T T T T T S T T T
T T T T T T T T T T T T S T T T
T T T T T T T T T T T T S T T T
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Frame No

Mapping


f
C0
C1
C2
C3
F S B B B B C C C C F S C C C C
D0 D0 D0 D0 D1 D1 D1 D1 D2 D2 D2 D2 D3 D3 D3 D3
Stand alone Control Channel
Slow Associated Control Channel
Traffic Channel
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Frame No

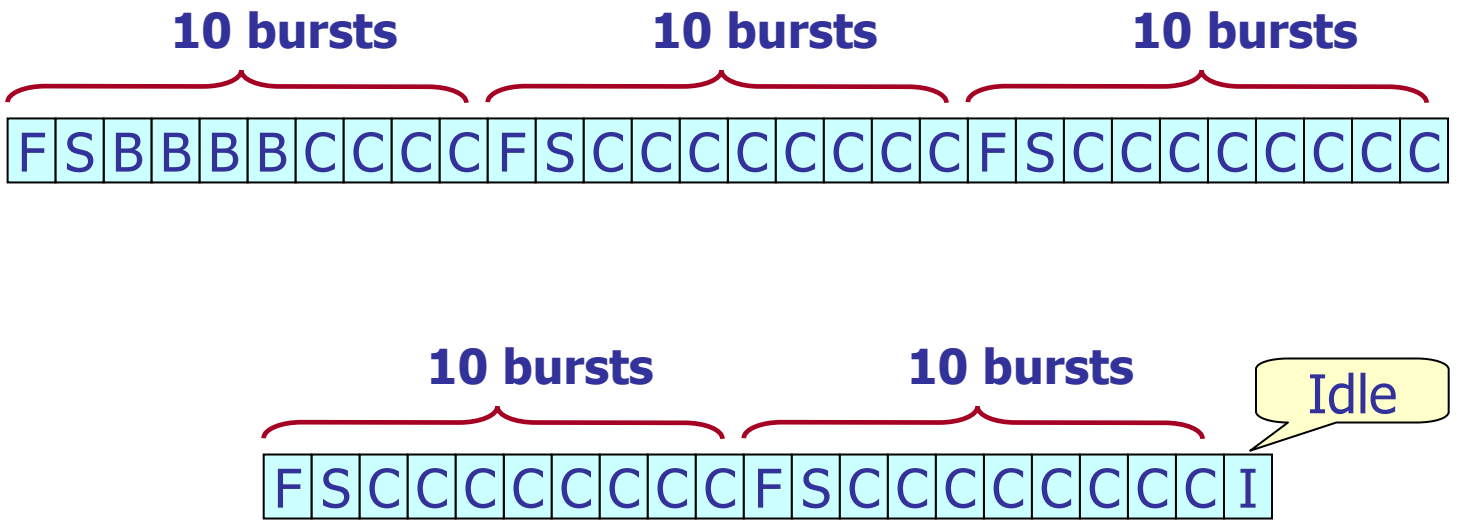
Traffic Multiframe (26 Frames)



It's repeated on C_0, $TS_{2\text{-}7}$ and all TS's on all other carriers

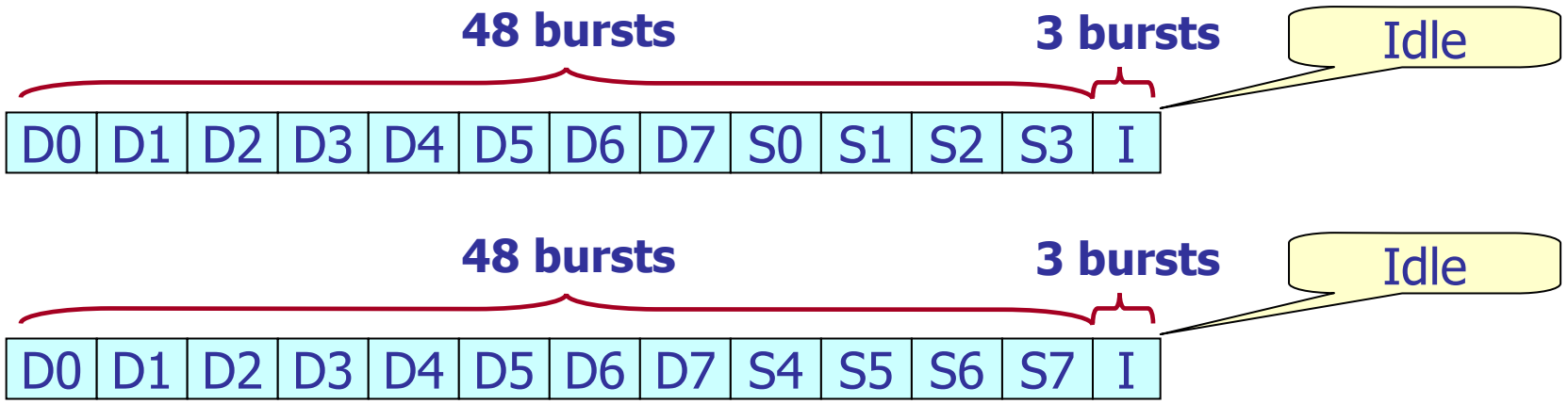
Control Multiframe (51 frames)

C_0, TS_0:



Control Multiframe (51 frames)

C_0, TS_1:



D:Stand alone (Call setup – SMS)

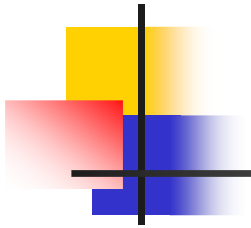
S:Slow Associated (Power Level-Time Advance)

TDMA Frame Structure

- 1 time slot = ***15/26 m.sec***
- 1 frame = 8 time slots = ***120/26 m.sec.***
- 1 traffic multiframe= 26 frame= ***120 m.sec***
- 1 Control multiframe= 51 frame= ***235 m.sec***
- 1 Super frame= 51 traffic*26 frame

  = 1326 frames = ***6.12 sec***
- 1 hyperframe= 2048 superframe

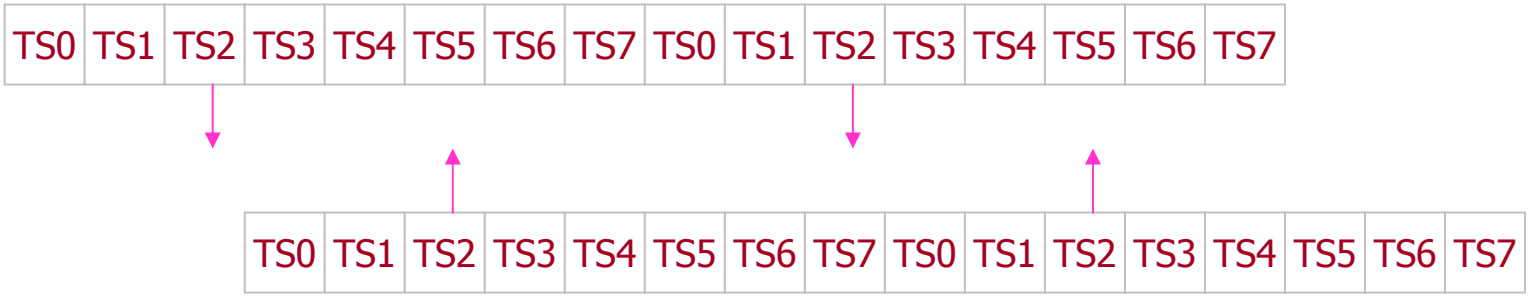
  = ***3 hours 28 minutes 53.76 sec***



- **Air Interface**
  - ➥ Rate = 270 kbps
  - ➥ 1 of 8 slots & 12 of 13 frames are used,
    Rate = 270*(1/8)*(12/13) = 31.15 kbps
  - ➥ 114 bits of 156.25 bits are useful,
    Rate = 31.15*(114/156.25) = 22.73 kbps
  - ➥ 9.73 kbps used for Error Correction,
    Rate = 22.73 - 9.73 = 13 kbps

Notes

- C_0 is called the beacon and is transmitted with the maximum available power in the cell.
- There is a 3 time slots time shift between the uplink and the downlink, this simplify the circuits and enable using one antenna and a duplexer.



Allocated GSM Frequency Bands

GSM900 ：
up: 890~915MHz
down: 935~960MHz
duplex interval: 45MHz
bandwidth: 25MHz，
frequency interval: 200KHz

EGSM900 ：
up: 880~890MHz
down: 925~935MHz
duplex interval: 45MHz
bandwidth: 10MHz，
frequency interval: 200KHz

GSM1800 :
up: 1710-1785MHz
down: 1805-1880MHz
duplex interval: 95MHz， working bandwidth: 75MHz，
frequency interval: 200KHz

GSM1900MHz:
up:1850~1910MHz
down:1930~1990MHz
duplex interval: 80MHz，
working bandwidth: 60MHz，
frequency interval: 200KHz

Diversity ion Technology

The multi-path propagation of radio signals causes magnitude fading and delay time.

- **Space Diversity (antenna diversity)**

- **Polarization Diversity**
  orthogonal polarization diversity.
  horizontal polarization and vertical polarization.

- **Frequency Diversity**
  The working principle of this technology is that such fading won't take place on the frequency outside the coherence bandwidth of the channel.