POLYTECH
PARIS-SUD

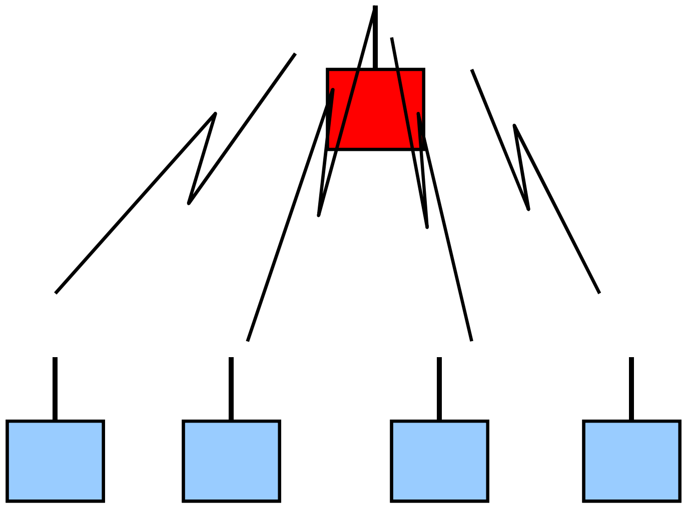
# *Réseaux Avancés*

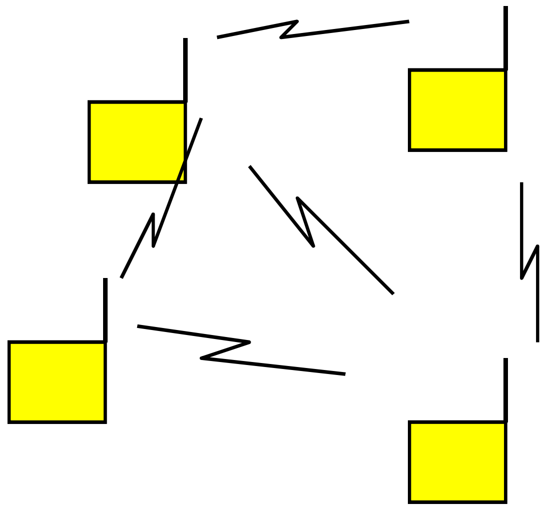
## Cellular Systems

# Broadcast channel

Centralized broadcast channel

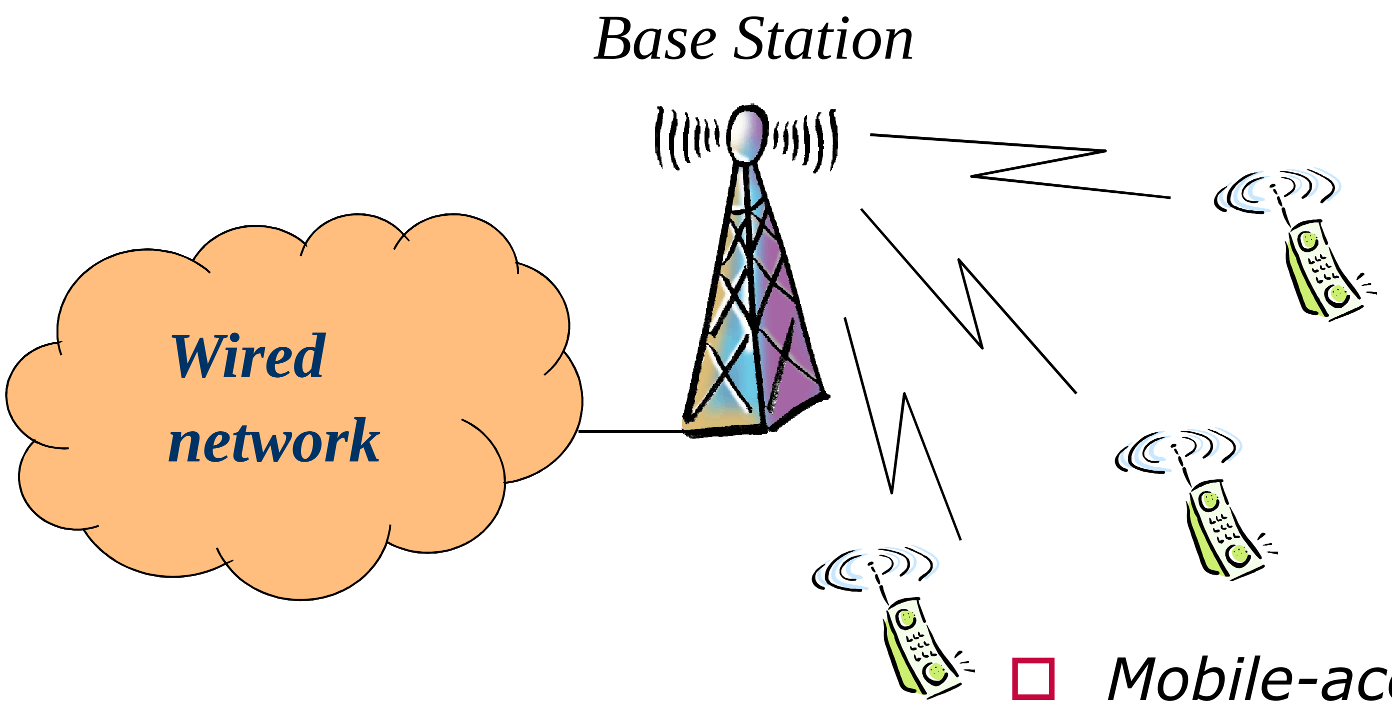
Distributed broadcast channel





# Centralized broadcast channel

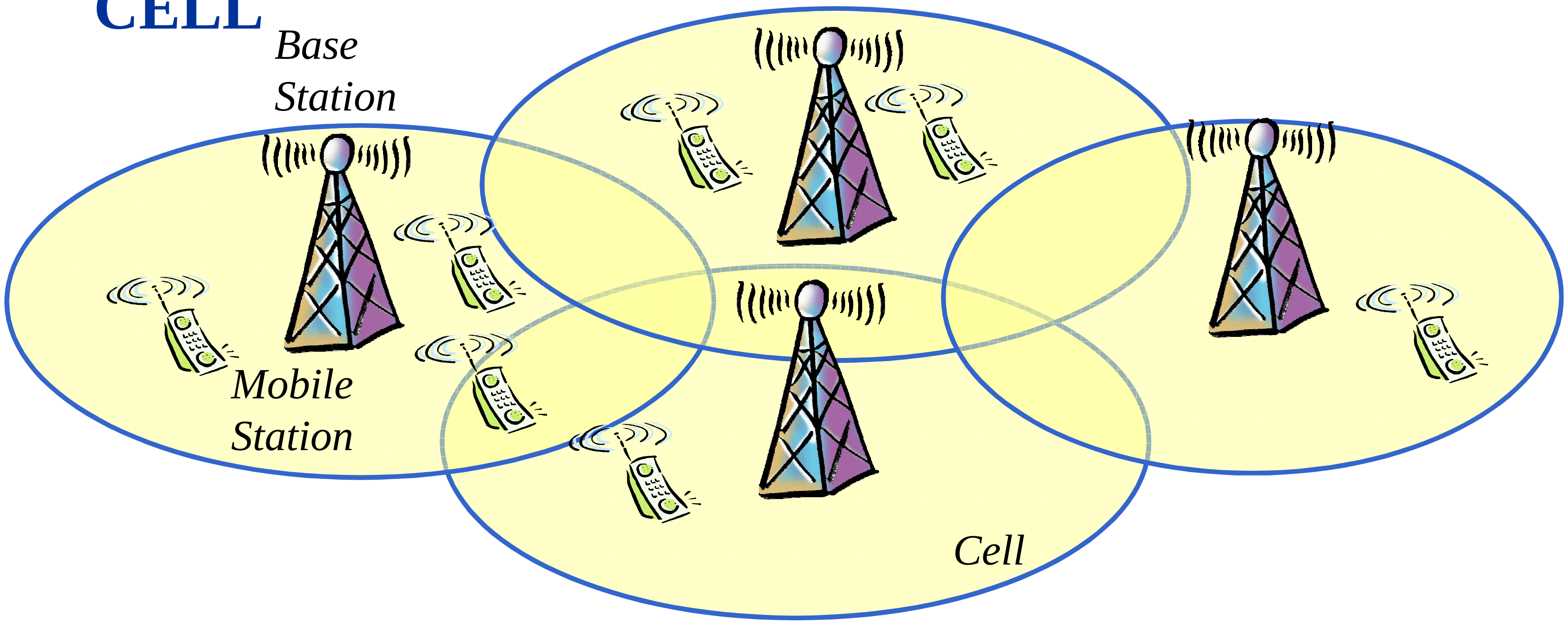
- **Fixed access point (<u>Cellular systems</u>, WLAN, WMAN …)**




- *Mobile-access point connection*

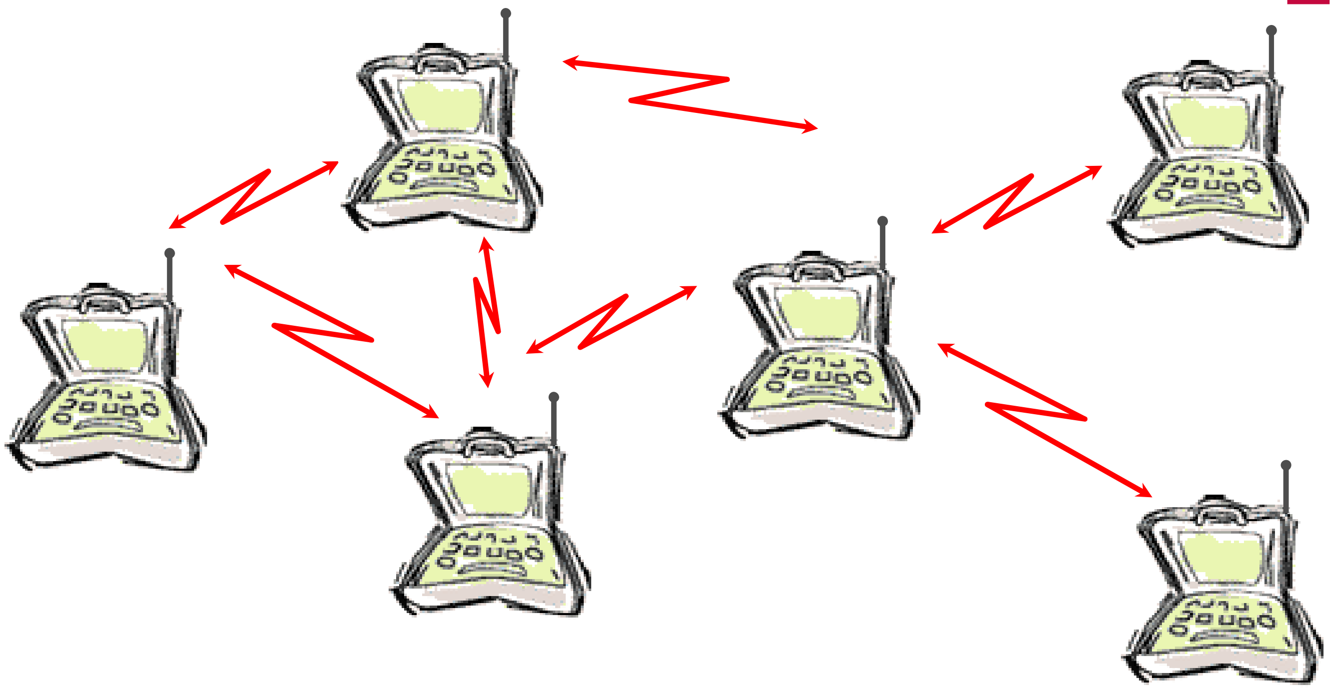
# Centralized broadcast channel

- **Cellular coverage: The territory coverage is obtained by Base Stations–BS (or Access Points) that provide radio access (Radio Access Network, RAN) to Mobile Stations–MS within a service area called CELL**



# Distributed broadcast channel

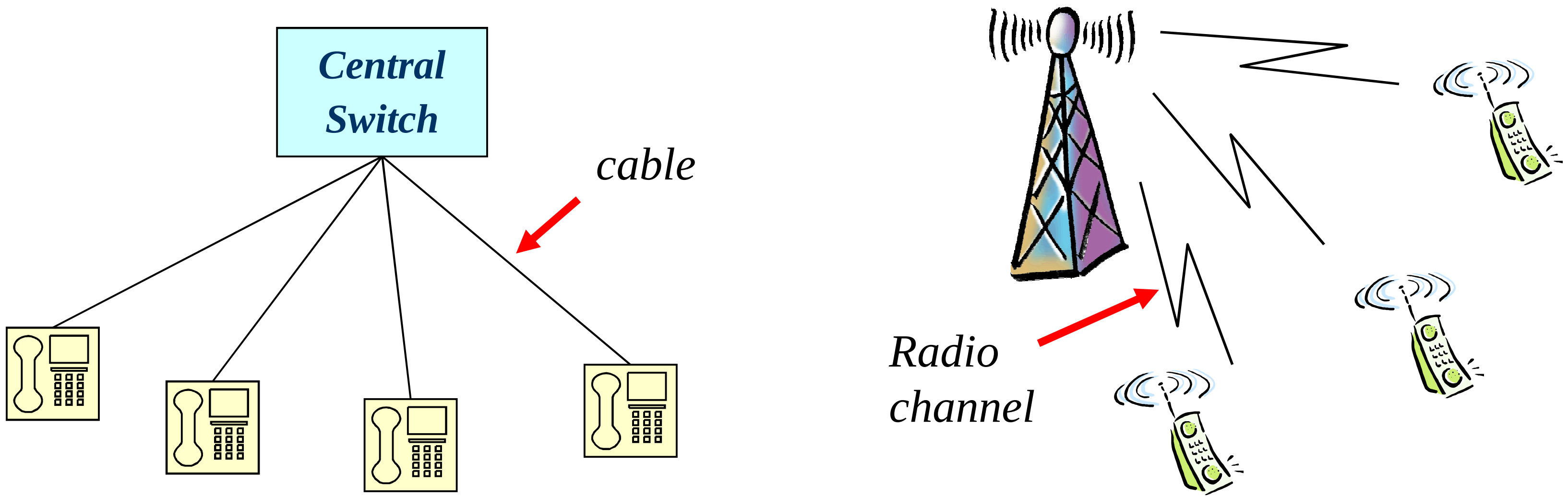
- **Ad-hoc wireless networks (mesh networks, sensor networks)**



- *mobile - mobile connections*

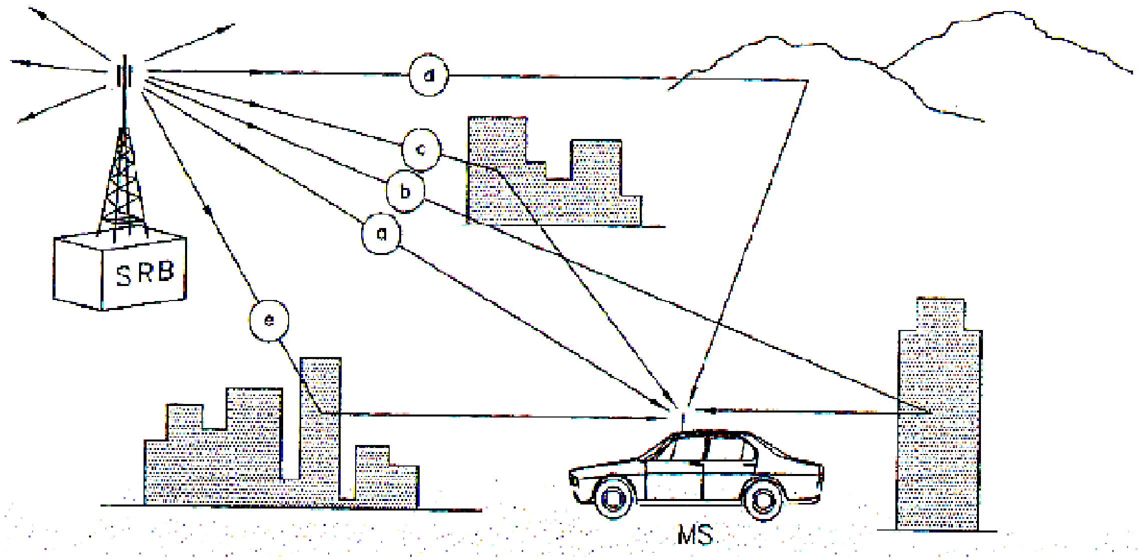
# Wired-Wireless networks: Main differences

- **Shared transmission medium**
  - ➔ **Multiple access mechanisms**
  - ➔ **Radio resource reuse**



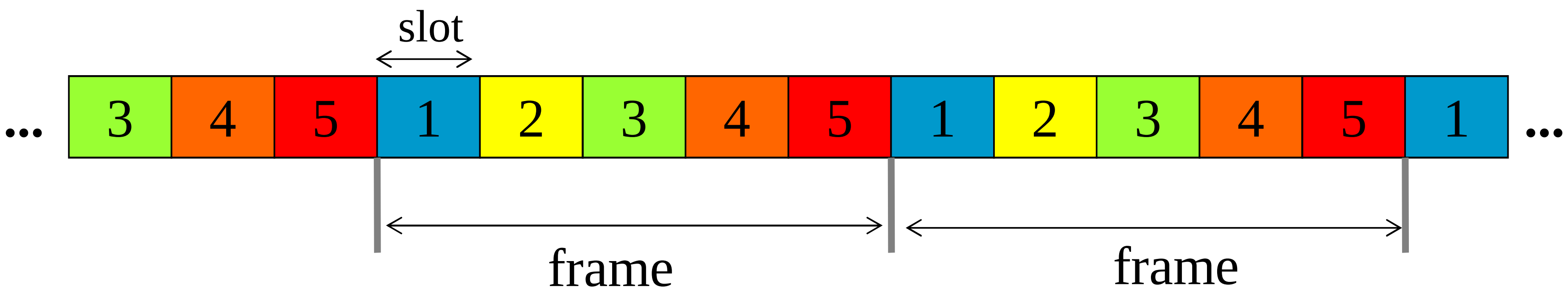
# Wired-Wireless networks: Main differences

- **Radio channel**
  - ➔ **Variable channel characteristics**
  - ➔ **Advanced modulation and coding schemes**



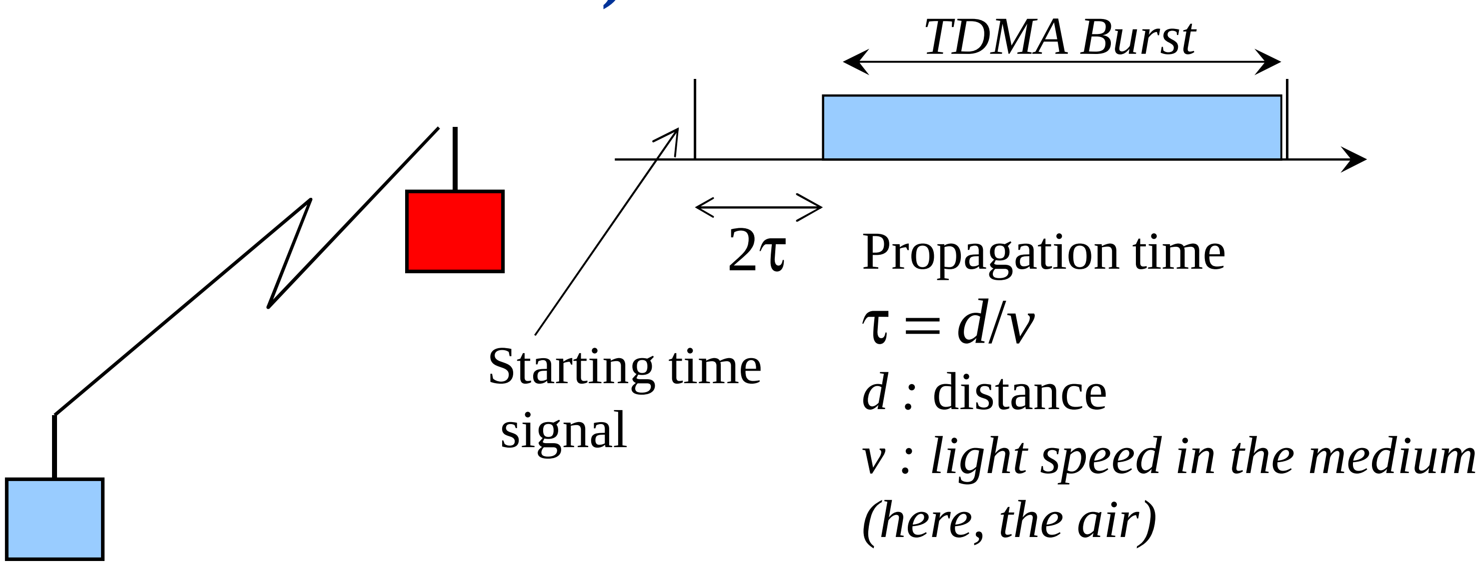
# TDM (Time Division Multiplexing)

- **Each source/sender can use only a single time slot every *N***
- **Hence we define a *frame structure*, where the frame is constituted by *N* consecutive time slots**
- **If we give a number to each time slot, each source/sender is associated to a time-slot number, and it can transmit only *inside* such slot**



# Centralized broadcast channel

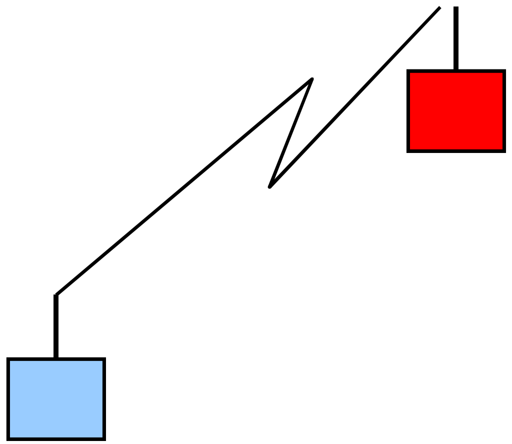
- **The Base Station is vital to enforce synchronization among mobile terminals**
- **Its transmissions are used to *synchronize* all transmissions (e.g., sending a signal to say when the frame starts)**

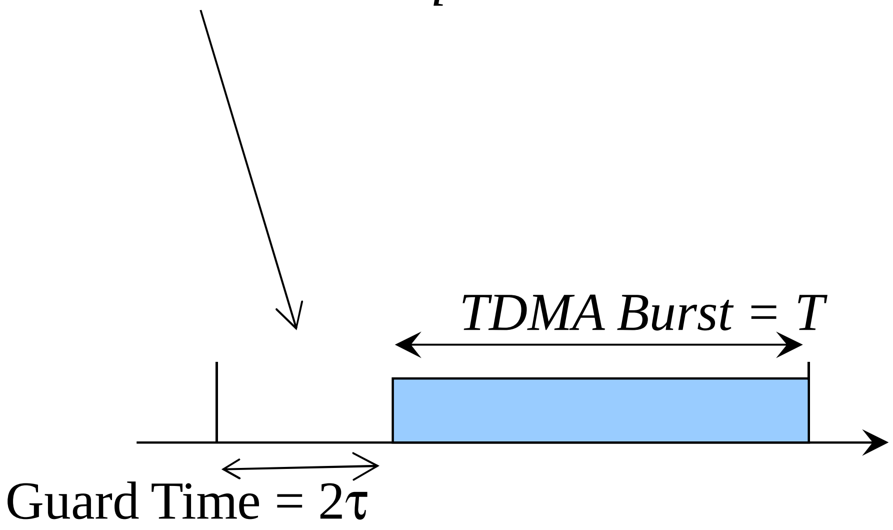


# Centralized broadcast channel

- **Guard time:**

$$T_g = \max_i (2\tau_i)$$



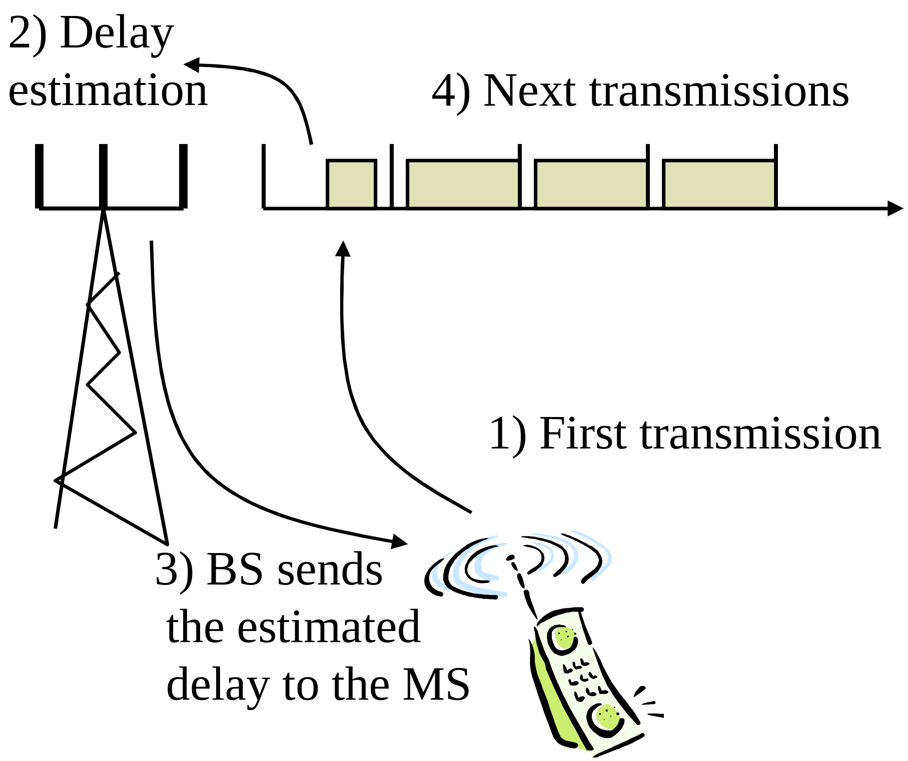



*Obviously: the guard time is dominated by the **farthest** node from the BS*

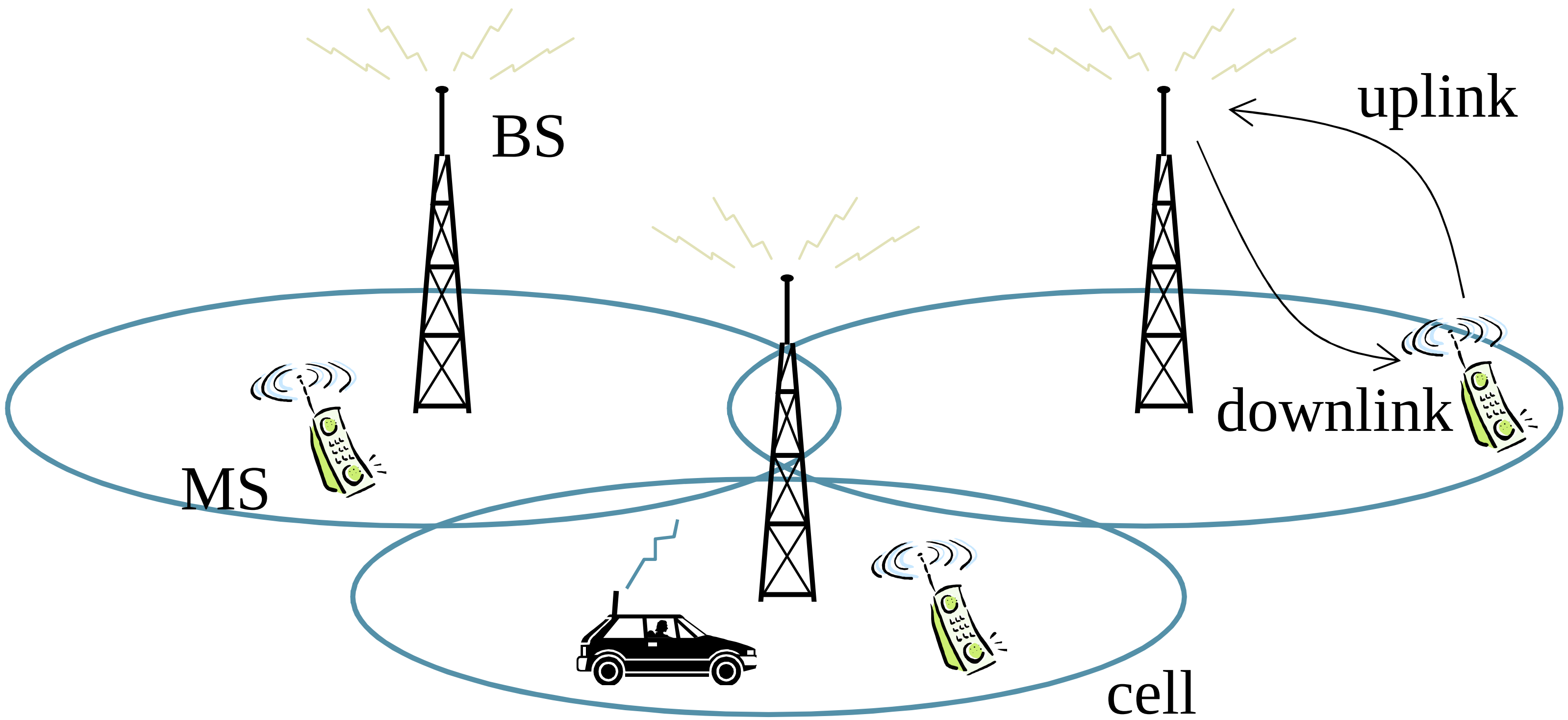
$$Efficiency = \frac{TDMA\ Burst}{TDMA\ Burst + Guard\ Time} = \frac{T}{T + 2\tau}$$

# Centralized broadcast channel

- **Timing Advance:**
  - **If each node knows the propagation delay towards the BS, it can anticipate its transmission!**
  - **Propagation delay τ must be estimated (it can be time-varying)**
  - **Estimation error is still possible: time guards are reduced, but they are not null!**
  - **Technique used in GSM**



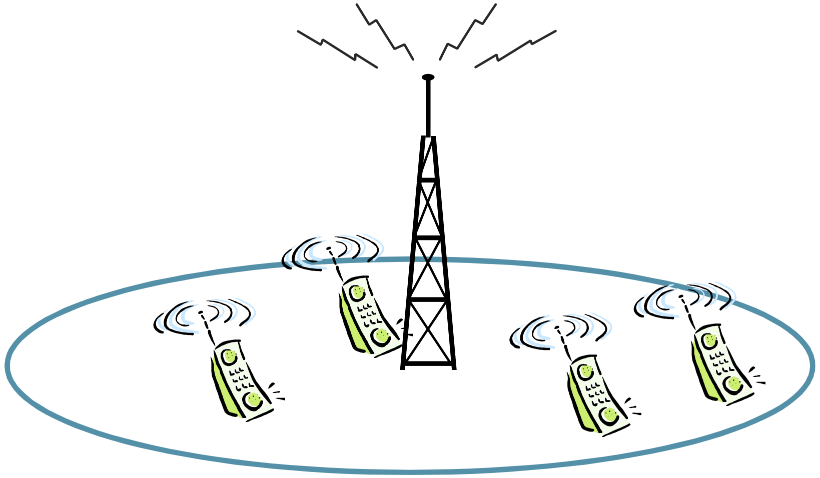
# Cellular (Mobile) Systems




MS = Mobile Station
BS = Base Station

Uplink = from the MS to the BS
Downlink = from the BS to the MS

# Radio Access

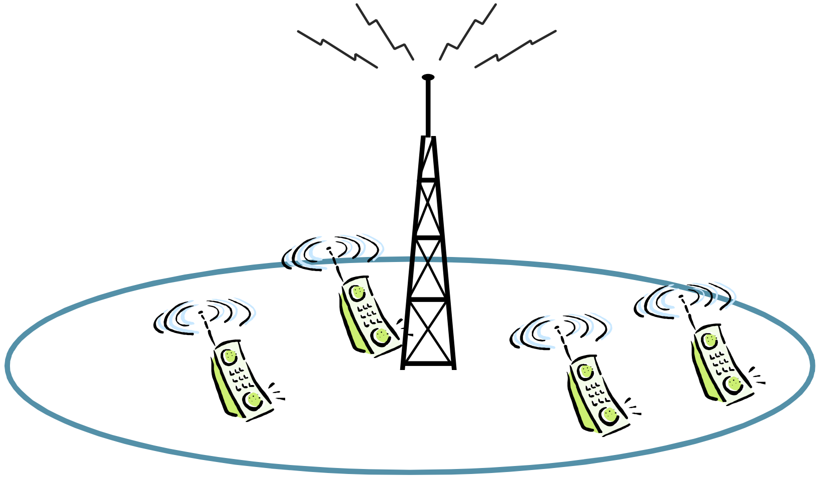


- The radio access problem is related to the way in which the users in the cell share radio resources

- downlink:
  - multiplexing is used

- uplink:
  - multiple access is used

# Radio Access



- 1st generation systems:
  - TACS (Europe)
    AMPS (US)
  - FDM/FDMA (downlink/uplink)

- 2nd generation:
  GSM (Europe)
  D-AMPS (US)
  - multi-carrier TDM/TDMA

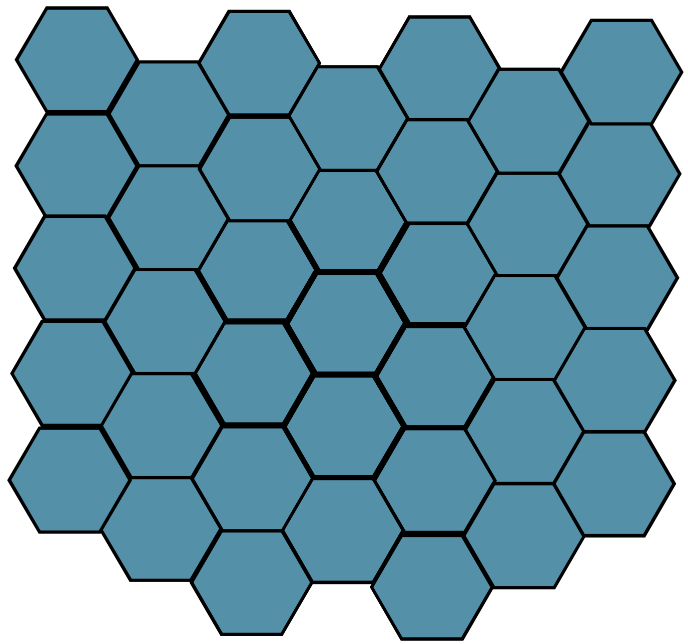
- 3rd generation:
  UMTS
  CDM/CDMA
- 4th generation
  LTE
  OFDMA/SC-FDMA
  (Single Carrier – FDMA)

# Frequency reuse

- **Available frequencies are not sufficient for all users**
- **Solution: we reuse the same frequency in different cells (*spatial reuse*)**
- **Spatial reuse causes *co-channel interference***
- **Spatial reuse is made possible if cells are sufficiently far apart so that interference can be small/tolerable (in order to guarantee a good quality of the transmitted signal)**

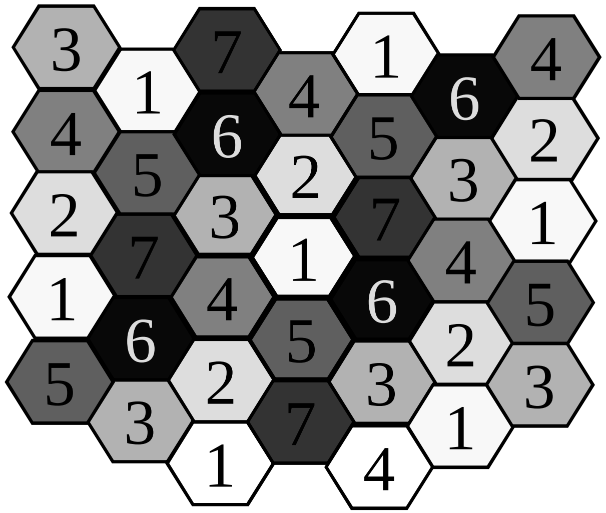
# Spatial reuse

- ***Interference*** **is therefore a fundamental, intrinsic feature of cellular systems**
- **Usually we assume that system quality is good when the ratio between the signal power and the interference power, named *SIR* (Signal-to-Interference Ratio) is higher than a predefined threshold, $SIR_{min}$**

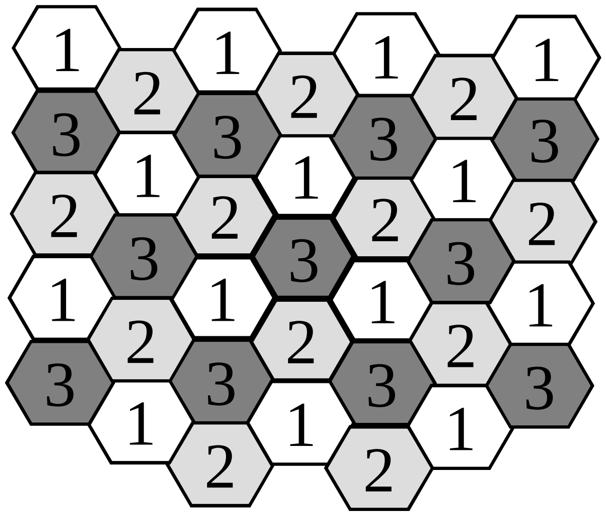


# Cluster dimensioning

- **All available frequencies are divided into K groups**
- **We assign a group to each cell in order to maximize the distance between 2 cells that use the same group of frequencies**
- **Frequency reuse efficiency = 1/K**
- **Possible K values: K=1,3,4,7,9,12,13, …**




K = 7




K = 3

# Cluster dimensioning

- **If we know/if we set the $SIR_{min}$ value tolerated by the system, then we can estimate the maximal efficiency of the system, i.e., the minimum K value that can be used**
- **Received power:**

$$P_r = P_t \cdot G \cdot d^{-\eta}$$

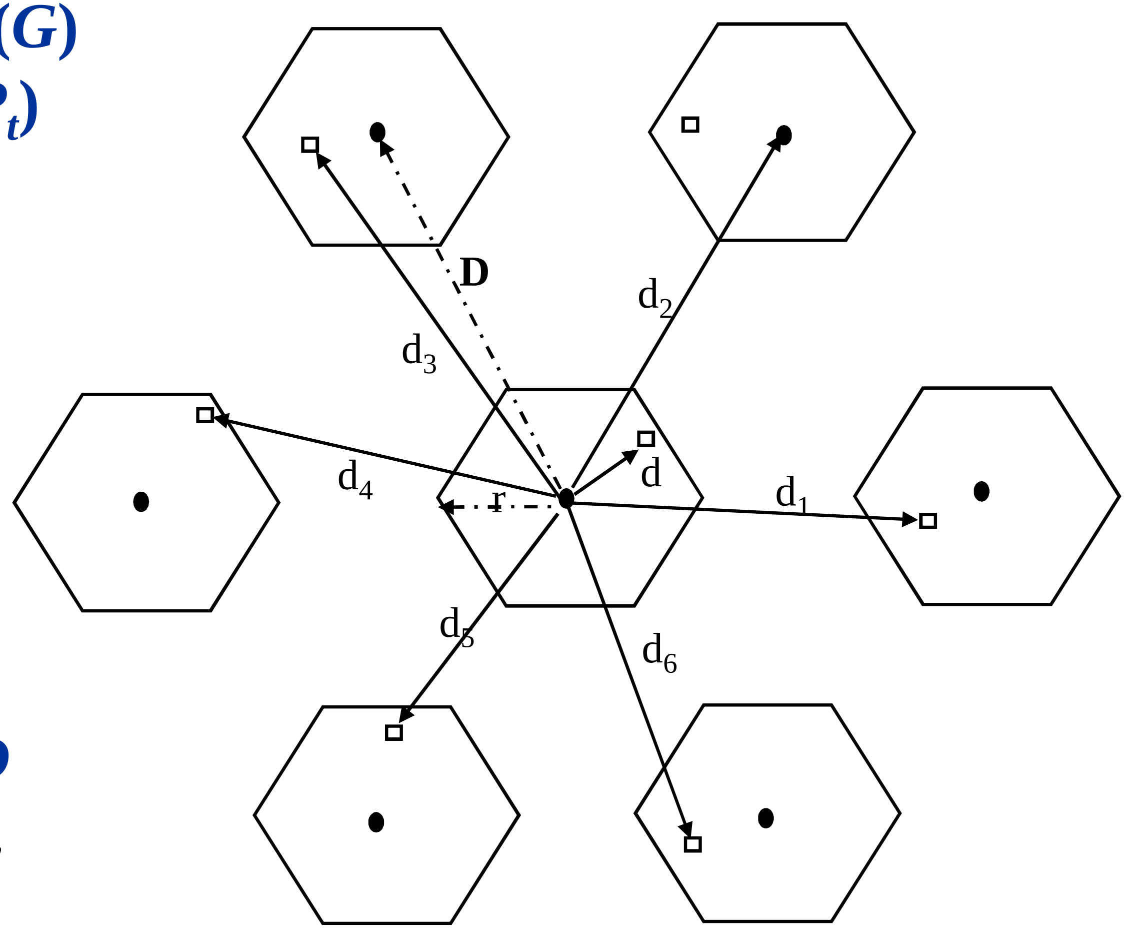
# Cluster dimensioning

- **Hip.: same antennas (*G*) and same tx power (*$P_t$*)**

$$SIR = \frac{P_t \cdot G \cdot d^{-\eta}}{\sum_{i=1}^{6} P_t \cdot G \cdot d_i^{-\eta}} = \frac{d^{-\eta}}{\sum_{i=1}^{6} d_i^{-\eta}}$$

- **Worst case: *d = r***
- **Approximation: *$d_i$ = D***

$$SIR \cong \frac{r^{-\eta}}{6D^{-\eta}} = \frac{1}{6}\left(\frac{1}{R}\right)^{-\eta}$$



# Cluster dimensioning

- **The SIR depends <u>exclusively</u> on the reuse ratio *R=D/r* (and on *η*) *but not* on the absolute transmission power or on the cell dimension**
- **If we fix $SIR_{min}$ we can compute $R_{min}$**
- **Then, if $R_{min}$ is known, we can obtain K since we can observe that:**

$$K = \frac{R^2}{3}$$

- **and therefore:**

$$K_{\min} = \frac{(6\,SIR)^{2/\eta}}{3}$$

# Exercise

- **Let us dimension a cluster for a cellular system that tolerates $SIR_{min}$ = 18 dB, considering the case where the path-loss exponent η is equal to 3.9**

$$K_{\min} = \frac{(6\,SIR)^{2/\eta}}{3} = \frac{(6 \cdot 63.1)^{2/3.9}}{3} = 6.99$$

## Summary

- **dB**
  - **Logarithmic scale**
  - **If we use absolute powers**

$$P_{dB} = 10\log_{10} P$$

$$P = 10^{P_{dB}/10}$$

# Summary

- The *product* in linear scale corresponds to a *sum* using dB
- The *ratio* corresponds to a *difference* in dB

$$G \cdot P \rightarrow G_{dB} + P_{dB}$$

$$P / A \rightarrow P_{dB} - A_{dB}$$

# Summary

- **Notable values**

$$2 \rightarrow 3dB$$

$$3 \rightarrow 4.77dB$$

$$4 = 2 \cdot 2 \rightarrow 3 + 3 = 6dB$$

$$5 \rightarrow 7dB$$

$$6 \rightarrow 7.77dB$$

$$8 \rightarrow 9dB$$

$$9 \rightarrow 9.54dB$$

$$10 \rightarrow 10dB$$

$$100 \rightarrow 20dB$$

$$1000 \rightarrow 30dB$$