Mobile and Ubiquitous Computing

Multiplexing for wireless

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Overview

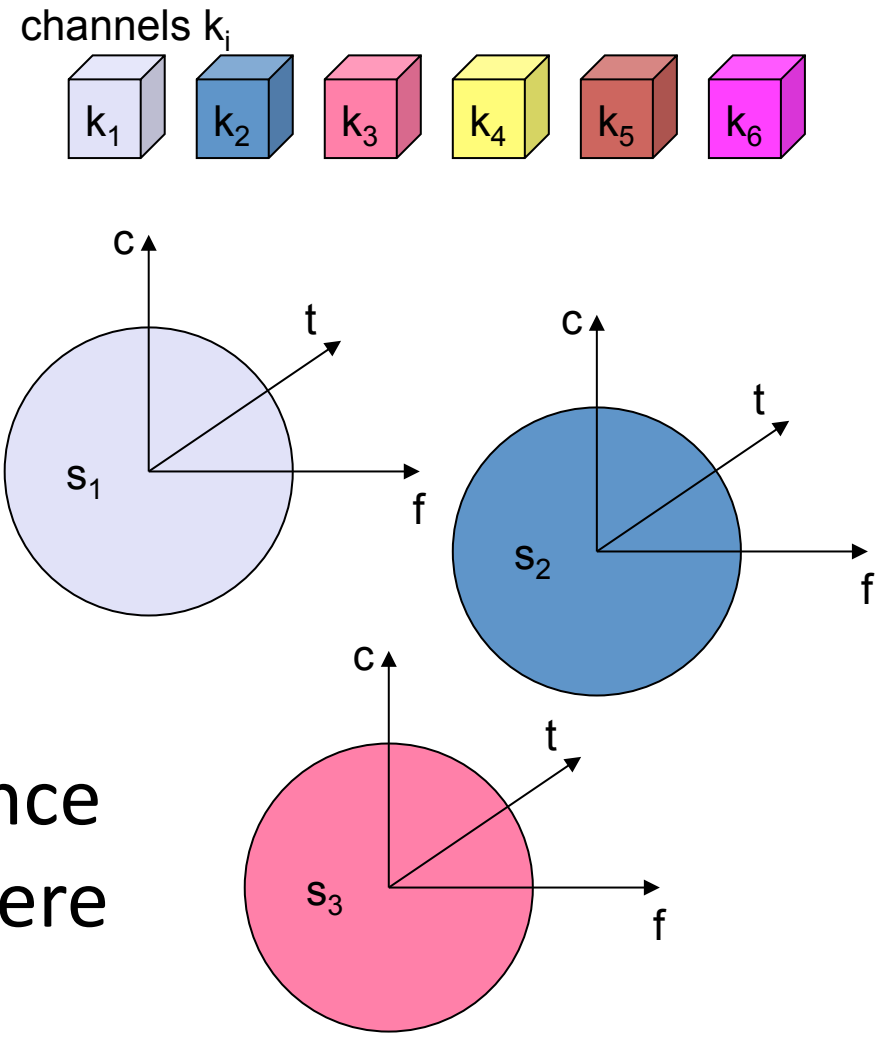
- Sharing the wireless (multiplexing)
  - in space
  - by frequency
  - in time
  - by code
- Putting it all together: cellular mobile nets

Multiplexing

- Goal: multiple use of a shared medium
- Take turns (requires organization)
- Multiplexing using signal parameters/ characteristics
  - space (s_i), time (t), frequency (f)
  - code (c)
- Important: guard spaces needed!

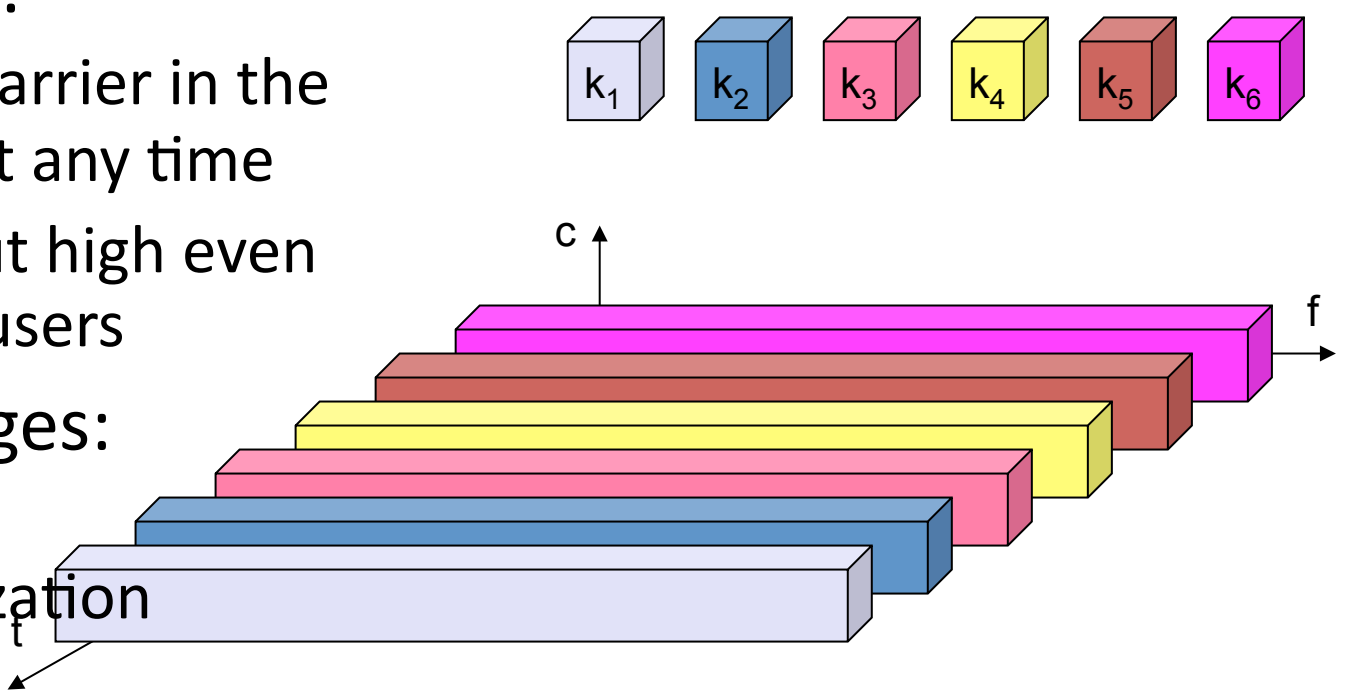
Multiplexing in space

- Each channel spatially separated by others
- Only one channel at each location
- Guard space is the distance between the regions where communication occurs



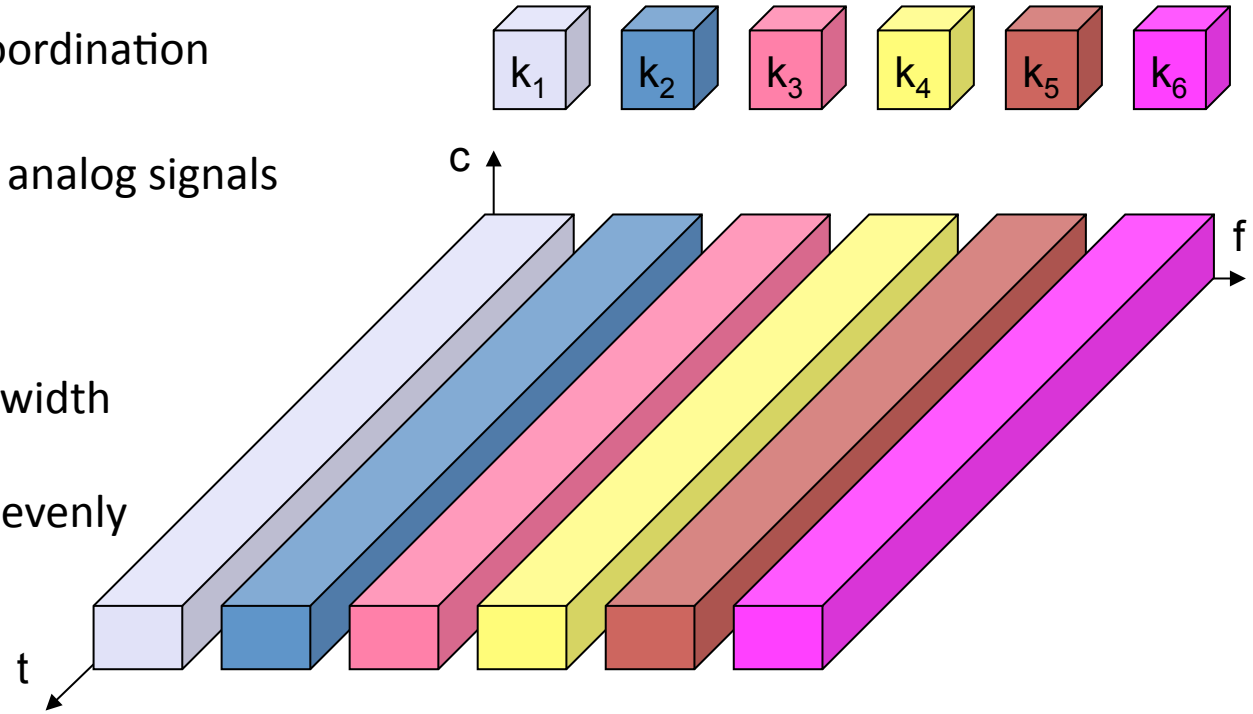
Time multiplex

- A channel gets the whole spectrum for a certain amount of time
- Advantages:
  - only one carrier in the medium at any time
  - throughput high even for many users
- Disadvantages:
  - precise synchronization necessary



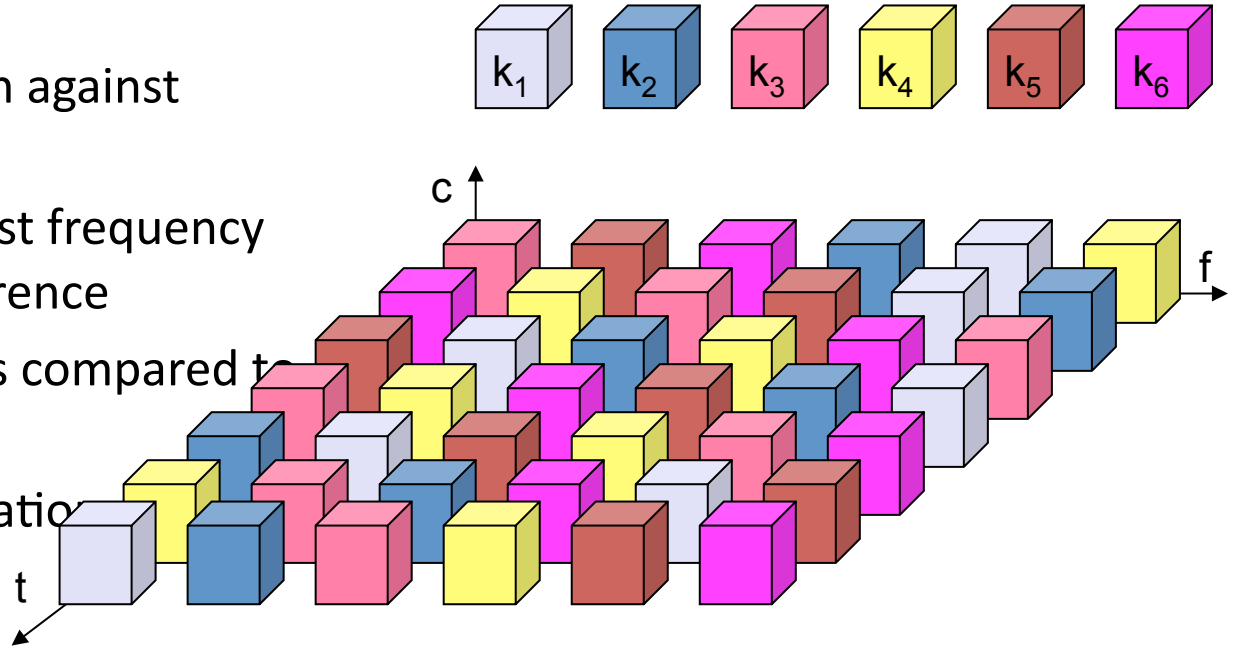
Frequency multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - no dynamic coordination necessary
  - works also for analog signals
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible
  - guard spaces



Time and frequency multiplex

- Combination of both methods
- A channel gets a certain frequency band for a certain amount of time
- Example: GSM
- Advantages:
  - better protection against tapping
  - protection against frequency selective interference
  - higher data rates compared t code multiplex
- but: precise coordinatio required



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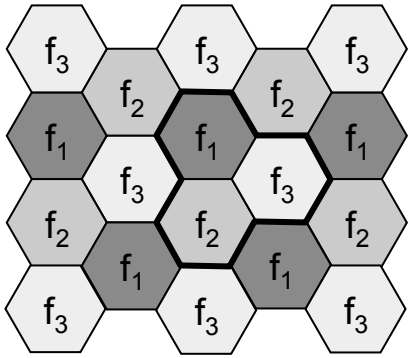
Example: Cellular Mobile

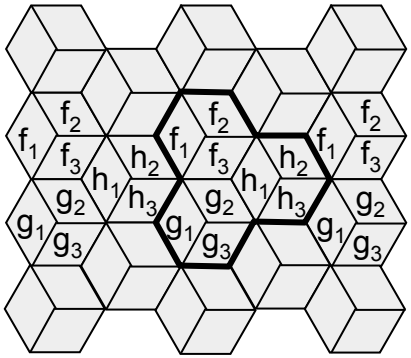
- Implements space division multiplex:
  - base station covers a certain transmission area (cell)
- Mobile stations communicate only via the base station
- Cell sizes range
  - from less than 100m in cities to as much as 35kn in rural areas for GSM

The same frequency *f* can be reused in different cells as long as they are far away from each other

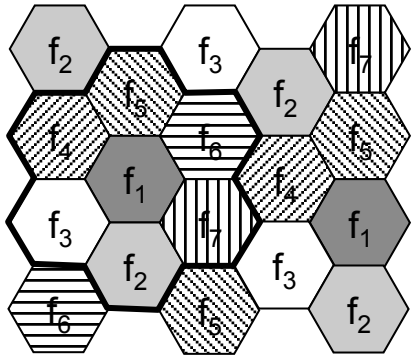
Separating cells: Frequency planning



3 cell cluster



3 cell cluster
with 3 sector antennas



7 cell cluster

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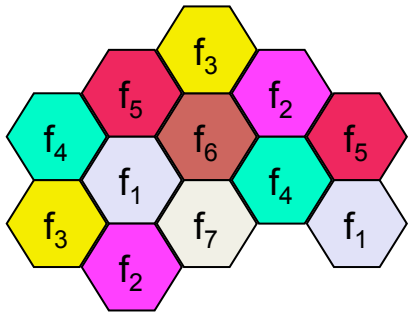
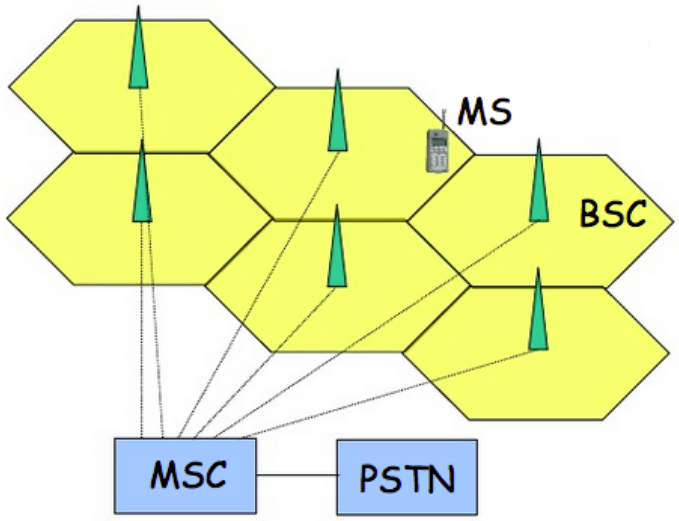
Example: GSM frequency planning

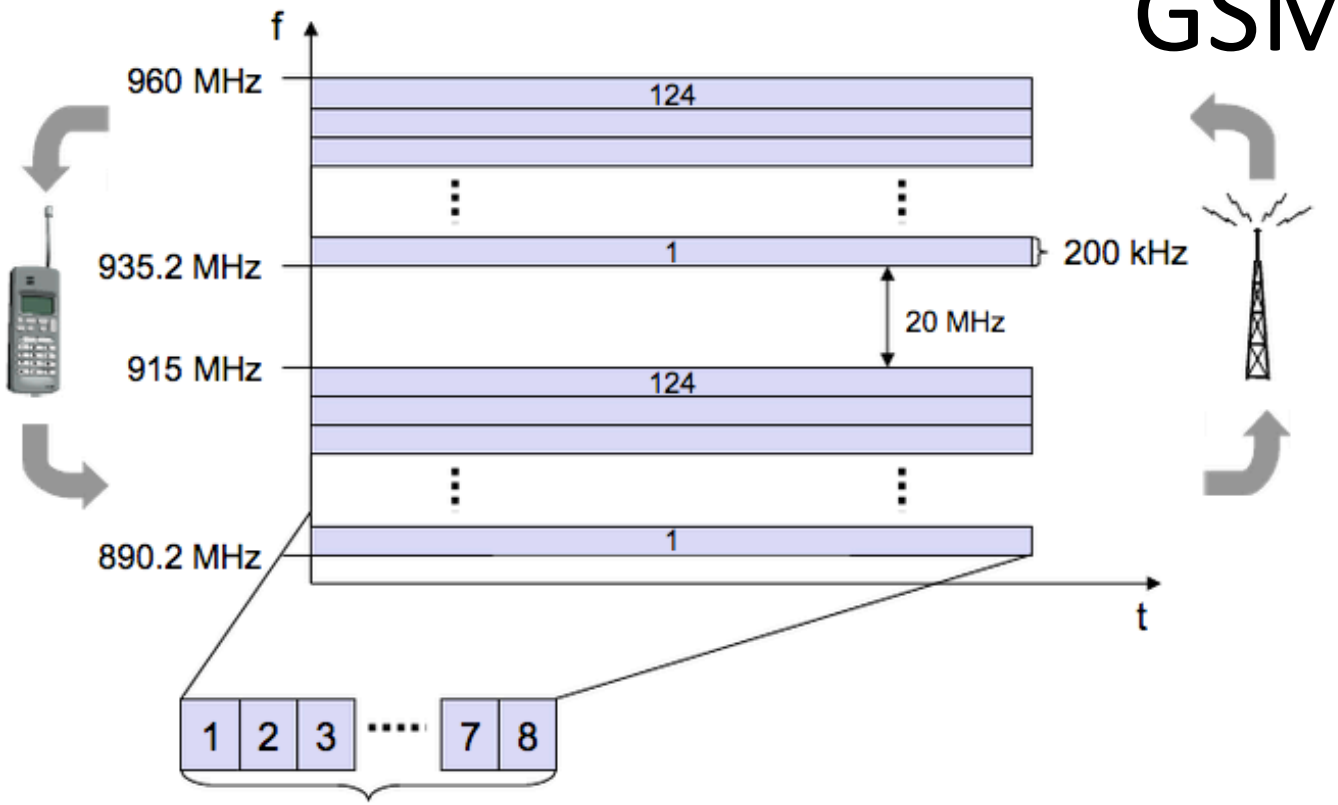
- Frequency reuse only with a certain distance between the base stations
- Standard model using 7 frequencies:





- MS: Mobile Station
- BSC: Base station controller
- MSC: Mobile switching center
- PSTN: Public switched telephone network

GSM FDMA



- 25 Mhz for BSC and 25 Mhz for MS + 100 kHz guard band
- Each frequency carrier is 200 kHz wide
- Total carriers 25 Mhz / 200 kHZ = 125

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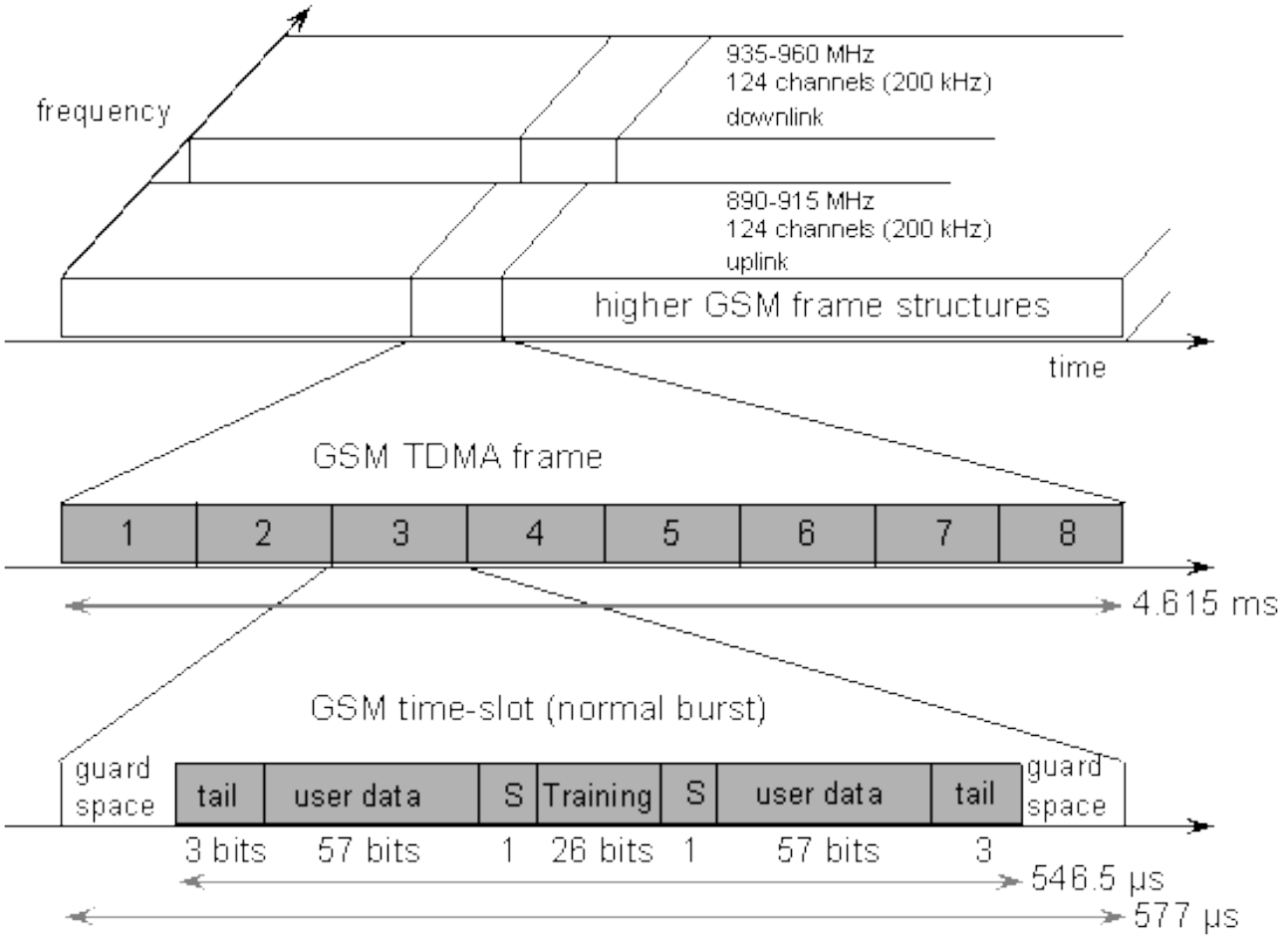
GSM TDMA



Source: www.cs.manchester.ac.uk

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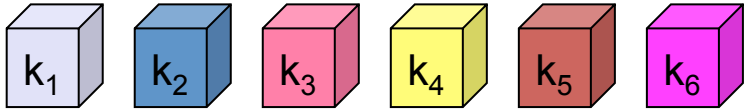
Dynamic GSM frequency planning

- Fixed frequency assignment:
  - certain frequencies are assigned to a certain cell
  - problem: different traffic load in different cells
- Dynamic frequency assignment:
  - base station chooses frequencies depending on the frequencies already used in neighbor cells
  - more capacity in cells with more traffic
  - assignment can also be based on interference measurements

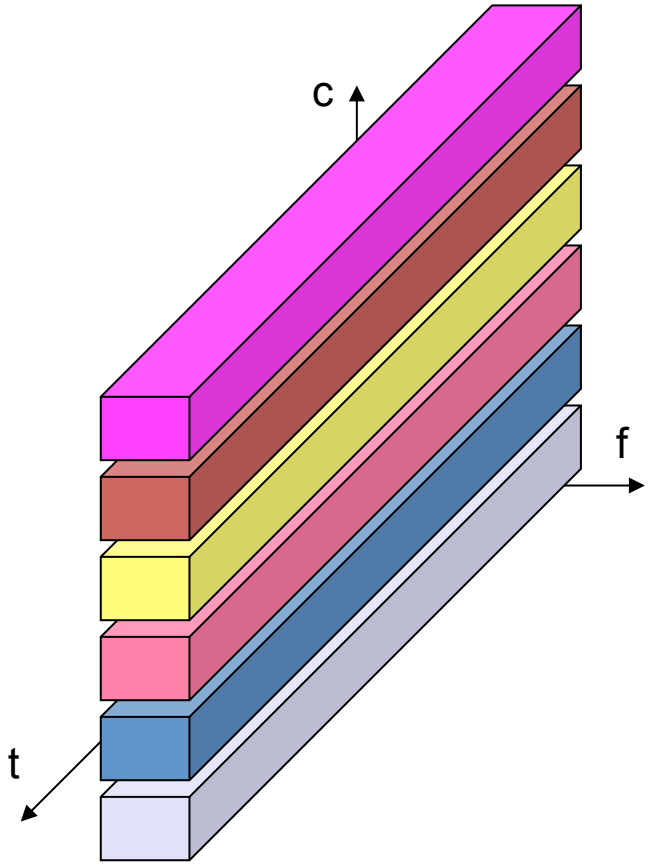
Advantages

- Advantages of cell structures:
  - higher capacity, higher number of users
  - less transmission power needed
  - more robust, decentralized
  - base station deals with interference, transmission area etc. locally
- Problems:
  - fixed network needed for the base stations
  - handover (changing from one cell to another) necessary
  - interference with other cells

Code multiplexing



- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
  - bandwidth efficient
  - no coordination and synchronization necessary
  - good protection against interference and tapping
- Disadvantages:
  - lower user data rates
  - more complex signal regeneration
- Implemented using spread spectrum technology



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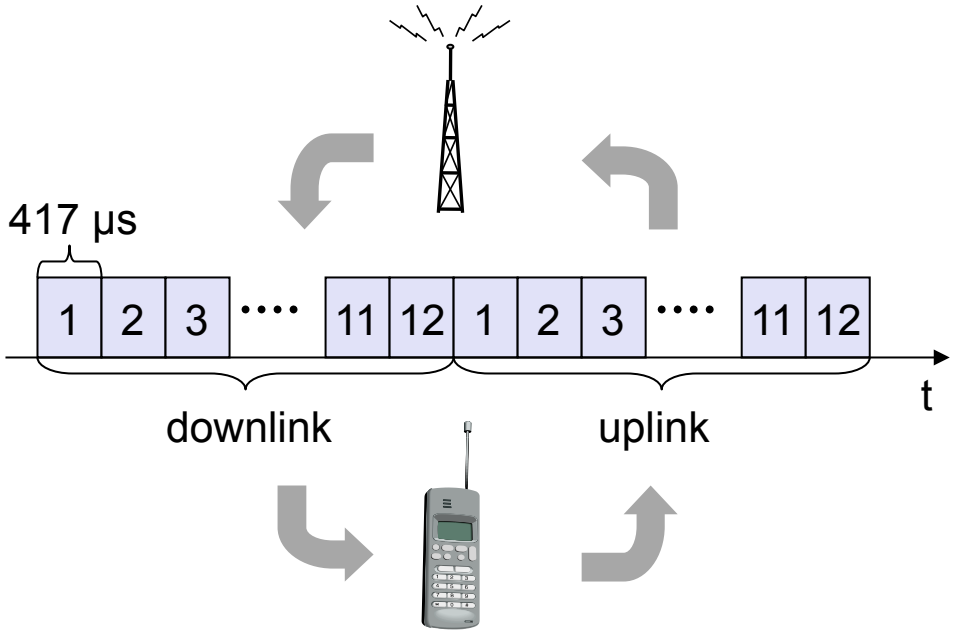
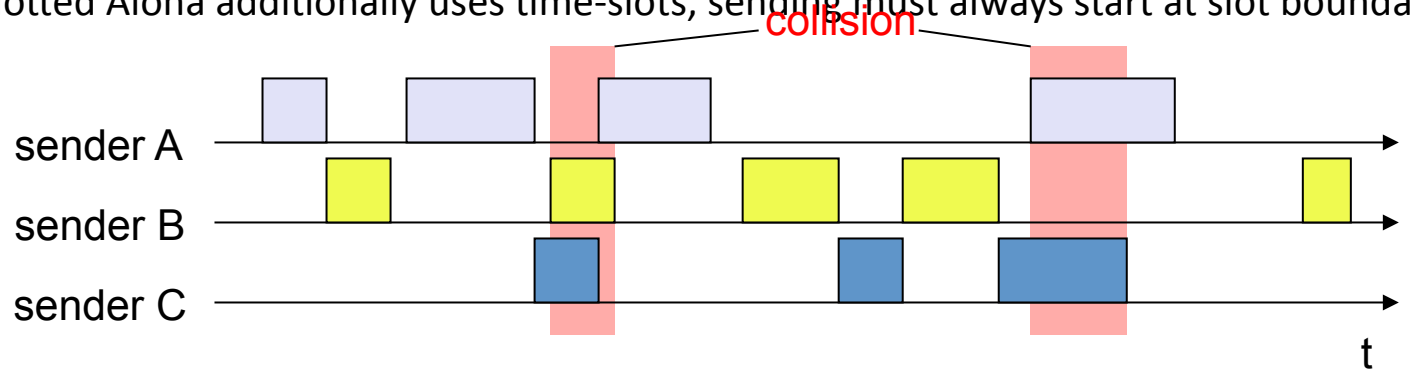
TDD/TDMA - general scheme



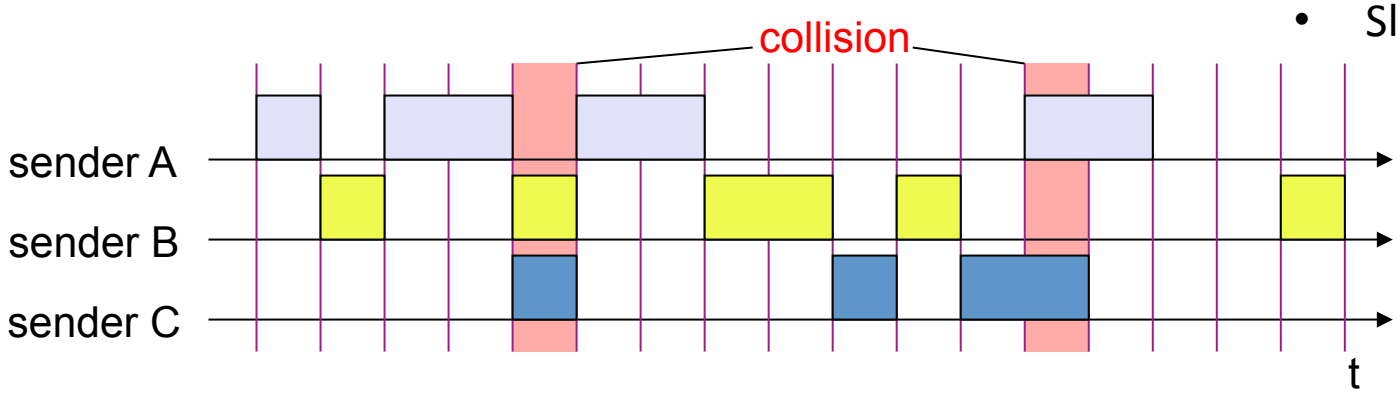
Aloha/slotted aloha

- Mechanism
  - random, distributed (no central arbiter), time-multiplex
  - Slotted Aloha additionally uses time-slots, sending must always start at slot boundaries

- Aloha



- Slotted Aloha



Demand Assigned Multiple Access

- Channel efficiency only 18% for Aloha, 36% for Slotted Aloha (assuming Poisson distribution for packet arrival and packet length)
- Reservation can increase efficiency to 80%
  - a sender *reserves* a future time-slot
  - sending within this reserved time-slot is possible without collision
  - reservation also causes higher delays
  - typical scheme for satellite links
- Examples for reservation algorithms:
  - *Explicit Reservation*
  - *Implicit Reservation (PRMA)*
  - *Reservation-TDMA*

Reservation-TDMA

- Reservation Time Division Multiple Access
  - every frame consists of N mini-slots and x data-slots
  - every station has its own mini-slot and can reserve up to k data-slots using this mini-slot (i.e. x = N * k).
  - other stations can send data in unused data-slots according to a round-robin sending scheme (best-effort traffic)