Multiplexing

Multiplexing in 4 dimensions
- space ($s_i$)
- time ($t$)
- frequency ($f$)
- code ($c$)

Goal: multiple use of a shared medium

Important: guard spaces needed!
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 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
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 to code multiplex

but: precise coordination required

Code multiplex

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
Spread spectrum technology

Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference.

Solution: spread the narrow band signal into a broad band signal using a special code.

Protection against narrow band interference.

Side effects:
- Coexistence of several signals without dynamic coordination.
- Tap-proof.

Alternatives: Direct Sequence, Frequency Hopping.

(More of this in 2nd semester)