ECS455: Chapter 5

OFDM

5.5 Remarks about OFDM

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Summary: OFDM Advantages

- For a given channel delay spread, the **implementation complexity** is much lower than that of a conventional single carrier (SC) system with *time domain equalizer*.
- **Spectral efficiency** is high since it uses overlapping orthogonal subcarriers in the frequency domain.
- Modulation and demodulation are implemented using inverse discrete Fourier transform (IDFT) and discrete Fourier transform (DFT), respectively, and fast Fourier transform (FFT) algorithms can be applied to make the overall system **efficient** (computationally).
- **Capacity** can be significantly increased by **adapting the data rate per subcarrier** according to the signal-to-noise ratio (**SNR**) of the individual subcarrier.

Example: 802.11a

Parameter	IEEE 802.11a
Bandwidth	20 MHz
Number of sub-carriers N_c	52 (48 data + 4 pilots) (64 FFT)
Symbol duration	4 µs
Carrier spacing F_s	312.5 kHz $= \frac{1}{4 - 0.8[\mu s]}$
Guard time T_g	0.8 µs
Modulation	BPSK, QPSK, 16-QAM, and 64-QAM
FEC coding	Convolutional with code rate 1/2 up to 3/4
Max. data rate	54 Mbit/s

OFDM Drawbacks

- **High peak-to-average power ratio (PAPR)**
  - The transmitted signal is a superposition of all the subcarriers with different carrier frequencies and high amplitude peaks occur because of the superposition.
- High sensitivity to **frequency offset**:
  - When there are frequency offsets in the subcarriers, the orthogonality among the subcarriers breaks and it causes intercarrier interference (ICI).
- A need for an adaptive or coded scheme to overcome **spectral nulls** in the channel
  - In the presence of a null in the channel, there is no way to recover the data of the subcarriers that are affected by the null unless we use rate adaptation or a coding scheme.

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5.6 OFDM-Based Multiple Access Techniques

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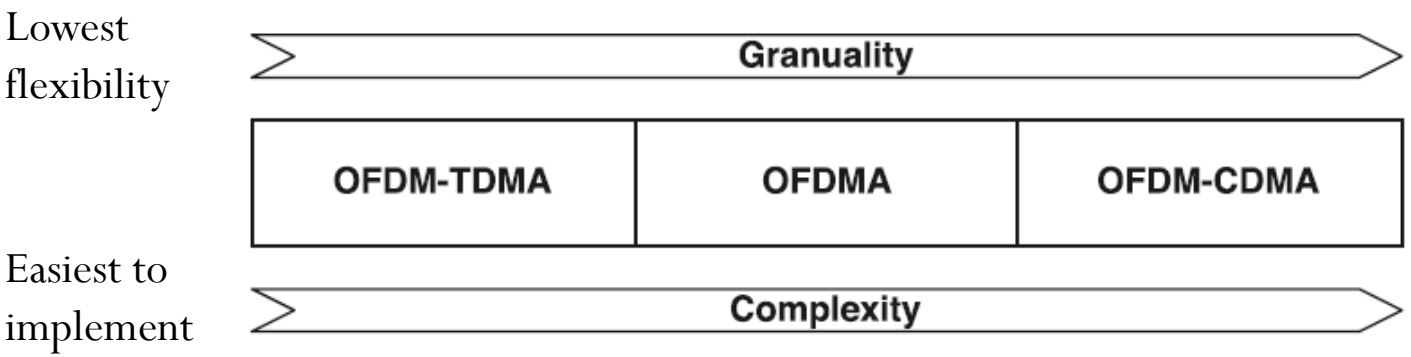
OFDM-based Multiple Access

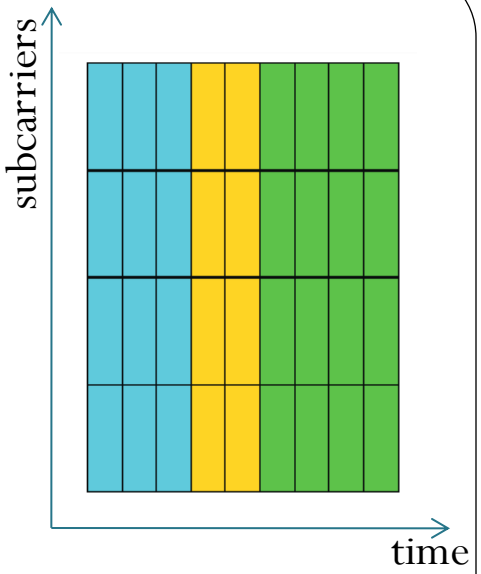
1. OFDMA (OFDM + FDMA + TDMA)
2. OFDM-TDMA
3. Multi-Carrier CDMA (OFDM-CDMA)



[Tarokh, 2009, Section 2.9, Fig 2.10]

OFDM-TDMA

- Users are separated via **time slots**.
- A particular user uses **all** sub-carriers within the predetermined TDMA time slot.
- Example: 802.11
  - Each user uses OFDM modulation and gets **transmission right** through the MAC layer channel access mechanism.



OFDM-TDMA (2)

- **Advantage**:
  - MS can **reduce** its **power consumption**
    - Process only OFDM symbols which are dedicated to it.
- **Disadvantage**:
  - Allocate the whole bandwidth to a single user
    - A reaction to different subcarrier attenuations could consist of leaving out highly distorted subcarriers

OFDMA

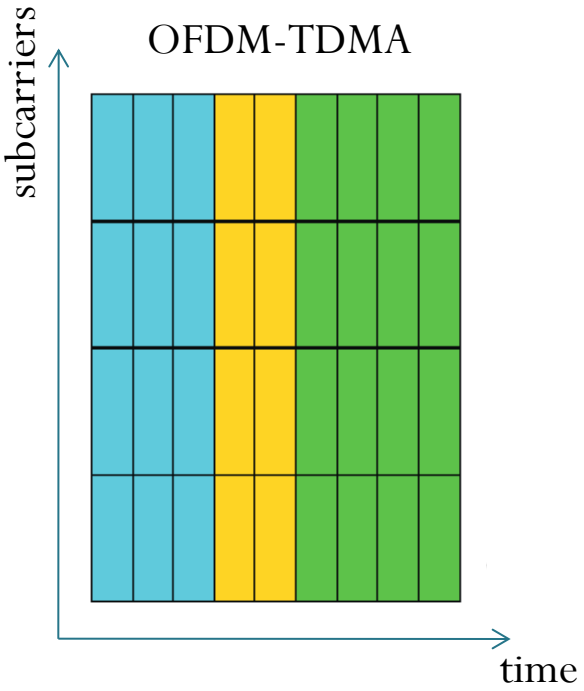
- Available subcarriers are distributed among all the users for transmission at any time instant.
- The fact that each user experiences a different radio channel can be exploited by allocating only "good" subcarriers with high SNR to each user.
  - *Recall*: For OFDM system, based on the **subchannel condition**, **different** baseband **modulation schemes** can be used for the individual subchannels
- The number of subchannels for a specific user can be varied, according to the required data rate.

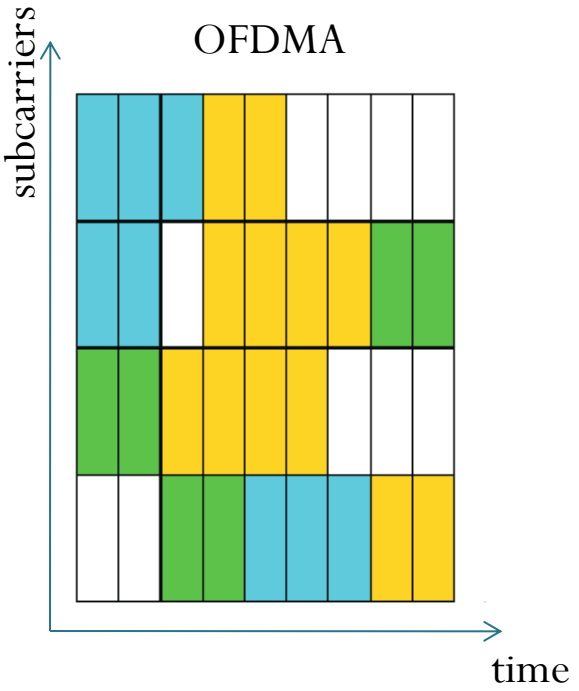
OFDM-TDMA vs. OFDMA

User 1

User 2

User 3





OFDMA Block Diagram