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CS 598: Advanced Wireless Networks and the Internet of Things

# Narrowband vs Wideband Channels

- narrow vs wide refers to bandwidth → symbols / second
- why do we use wideband: more bandwidth ⇒ more data rate

$$\text{capacity} = \text{bandwidth} * \log(1 + \text{SNR})$$

- having more bandwidth means for the same SNR, you have more capacity

## Challenges of wideband

1. **Inter-Symbol Interference (ISI)**
    - with multipath symbols, you get multiple copies @ different times and strengths at the receiver
    - lower bandwidth leads to longer symbols (timewise) (so higher bandwidth = shorter symbols)
    - smaller symbols means there is more ISI confusion
    - if there is a bit of overlap between different symbols that arrived at the same time because of the delay → leads to confusion on what symbol it should be read as
2. **Channel Itself**
    - simple equation for channel: $y = hx + n$ → but too simple for wideband
    - more realistic (but complicated) equation:

$$y(t) = h_1 x(t - \mathrm{T}_1) + h_2 x(t - \mathrm{T}_2) + h_3 x(t - \mathrm{T}_3)$$

   → T_n is the delay, which is more relevant in wideband (but trivial in narrowband)

## Combatting wideband challenges

- in general, we know that wideband channels occupy more spectrum/frequency.
- the assumption that the channel is flat, however, does not really hold because of multipath fading
- Solution:
    - divide the wideband channel into many narrowband channels
    - these split channels operate like narrow band channels → subchannel/subcarrier
    - basically, this parallelizes the channels, so we get the benefits of both narrow and wide bands
- What if the narrow channels seep into the neighboring frequencies?
    - use every other frequency band

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# Orthogonal Frequency Domain Multiplexing (OFDM)

## Motivation

- we want to design combinations where the peak of one of these channels has all the other channels' leak at 0. → minimized interferences
- try to find the mathematical pattern for this:

Distinct Fourier Transform (DFT):

- used to convert between time and frequency domains.
- equivalent to what we want above. </aside>

## The Process/How

- We want to send $x_1 ...x_n$ symbols in parallel
  - these symbols start out in the frequency domain ⇒ DFT ⇒ time domain peaks ⇒ wideband now can transmit this out.

$$x_f = \sum_{n=0}^{N-1} x_n \, e^{\frac{j2\pi f_n}{N}}$$

- essentially, these are now linear combinations of all the other frequencies without any interference with each other
- this is computationally expensive, however, so it was not used much until recently
- important to note: all of these sub-bands are serving the same transmitter

## OFDM Transmitter

- center frequency is that at the center of the frequency band.
- bits → symbols → [DFT] → symbols in the time domain → [add the carrier frequency] → send through antenna

## OFDM Receiver

- at the antenna, keep sampling
- use 2 windows, and take the ratio of Window A/Window B
- ratio starts at 1, as A starts to see the signal, the ratio between the two increases. When B starts to enter the signal, we get ratio=1 again → sliding window packet detection
  - we know where the packet starts based on the peak of the ratio.