Scalable OFDMA

Silicon DSP Corporation

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Hassan Yaghoobi, “**Scalable OFDMA Physical Layer in IEEE 802.16 WirelessMAN**”, *Intel Technology Journal*, Volume 8, Issue 3, 2004

- The worst case rms delay spread for fixed wireless access from the SUI models is SUI-6 (Terrain Type A: hilly terrain with moderate-to-heavy tree densities) 5.24 μs.

- The International Telecommunications Union (ITU-R) Vehicular Channel Model B shows delay spread values of up to 20 μs for mobile environments.

- The subcarrier spacing design requires a flat fading characteristic for worst-case delay spread values of 20 μs.

Coherence Bandwidth for 20 μs

$$B_c \approx \frac{1}{5 \cdot \sigma_\tau} = \frac{1}{5 \cdot 20\mu s} = 10KHz$$

So we need around 10 kHz carrier spacing to have flat fading per carrier.

Now, consider the expression:

$$f_s = floor(\frac{8}{7}\frac{BW}{8000})8000$$

$$\Delta f = \frac{f_s}{N_{FFT}}$$

To keep Δf

at around 10 kHz,

then if we decrease the bandwidth, then we have to *decrease* the number of points in the FFT.

This is the idea behind scalable OFDMA.

Benefits

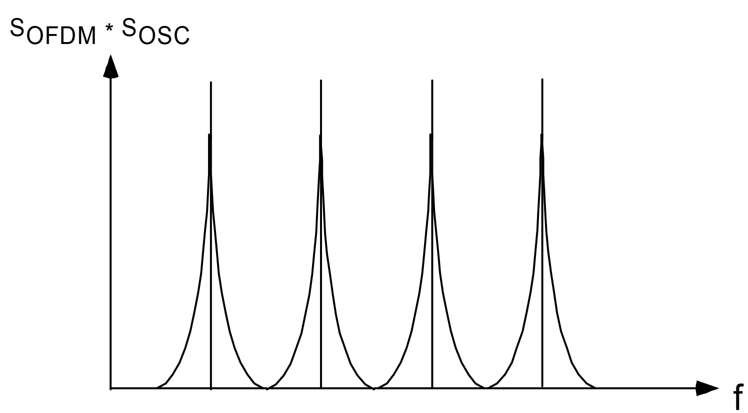
There is another added benefit to scaling the FFT length with bandwidth.

If we keep N_{FFT} the same then as we decrease the bandwidth the carrier spacing becomes very small.

This creates a problem with *phase noise*.

Also for Inter Carrier Interference with *Doppler spread*.

“An OFDM system is also sensitive to phase noise and the negative impact of impairment increases for narrower subcarrier spacing, which makes the design more expensive and complex.”



Inter Carrier Interference and Doppler Spread

v = 35 m/s

T_s Symbol Duration

$$P_{ICI} \leq \frac{1}{12}(2\pi f_d T_s)^2$$

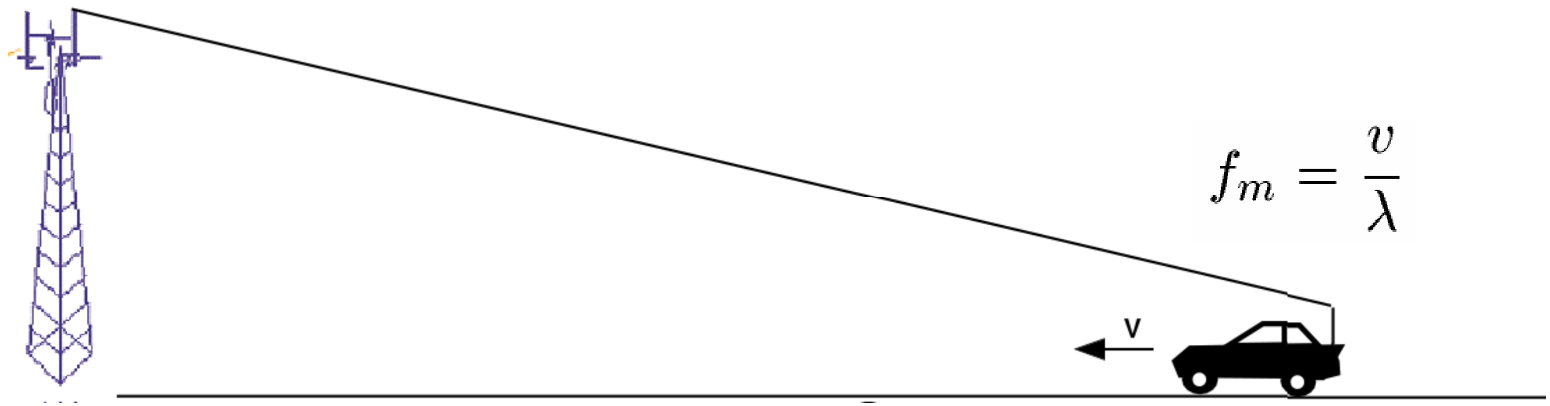
$$P_{ICI} \leq \frac{1}{12}(2\pi \frac{f_d}{\Delta f})^2$$

f_c, GHz	f_d, Hz
3.5	408
6	700

$$\Delta f = 10\ kHz$$
$$f_d = 408\ Hz$$

$$P_{ICI} \leq 0.00548$$

$$P_{ICI} \leq -23\ dB$$



$$f_m = \frac{v}{\lambda}$$

Li, Cimini,"**Bounds on the Interchannel Interference of OFDM in Time-Varying Impairments**", *IEEE Transactions on Communications*, Vol. 49, No. 3, March 2001.

$$T_c = \sqrt{\frac{9}{16\pi f_m^2}}$$

v = 35 m/s

f_c, GHz	f_d, Hz	T_c, ms
3.5	408	1.04
6	700	0.60

Rappaport, T.S., *Wireless Communications Principles and Practice,* Second Edition 2002, Prentice Hall PTR, Upper Saddle River, NJ.

Scalable OFDMA Parameters

Parameters	Values				
System Bamdwidth (MHz)	1.25	2.5	5	10	20
Sampling Frequency (F_s, MHz)	1.429	2.857	5.714	11.429	22.857
Sample Time ($1/F_s$ nsec)	700	350	175	88	44
FFT Size (N_{FFT})	128	256	512	1024	2048
Subcarrier frequency Spacing	11.161 kHz				
Useful Symbol Time ($T_b=1/\Delta f$)	89.6 μsec				
Guard Time ($T_g=T_b/8$)	11.2 μsec				
OFDM Symbol Time (T_s)	100.8 μsec				

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Data Rate 1/8th CP

$$\text{DataRate} = \frac{N_{Data} b_m c_r}{T_s}$$

$$T_s = (T_b + \frac{T_b}{8}) = 1.125 T_b = \frac{1.125}{\Delta f}$$

$$\text{DataRate} = \frac{9}{8} N_{Data} b_m c_r \Delta f$$

$$\boxed{\text{DataRate} = \alpha N_{FFT} b_m c_r \Delta f}$$

$$\text{DataRate} = \alpha N_{FFT} b_m c_r \frac{f_s}{N_{FFT}}$$

$$\text{DataRate} = \alpha b_m c_r f_s$$

Example System Parameters

Parameters	Values
Operating Frequency	2500 MHz
Duplex	TDD
Channel Bandwidth	10 MHz
BS-to-BS Distance	2.8 kilometers
Minimum Mobile-to-BS Distance	36 meters
BS Height	32 meters
Mobile Terminal Height	1.5 meters
BS Antenna Gain	15 dBi
MS Antenna Gain	"-1" dBi
BS Maximum Power Amplifier Power	43 dBm
Mobile Terminal Maximum PA Power	23 dBm
BS Noise Figure	4 dB
MS Noise Figure	7 dB

Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation Prepared on Behalf of the WiMAX Forum, February 21, 2006, WiMAX Forum