PHY Design Considerations for 802.11af

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Abstract

- The document discusses existing OFDM PHY specification in clause 17 IEEE 802.11-2007 and possible modifications of the parameters to be used in 802.11af standard.
- Reason for those changes are mainly different channel parameters of TVWS band and 5 GHz band.
- It is noted that some of the key PHY parameters may require modification before they can be applied for 802.11af, especially to improve overall performance.

Channelization

- IEEE 802.11-2007
  - The OFDM PHY shall operate in the 5 GHz band.
  - The spectrum is channelized into 5 MHz band each;
  - The OFDM system provides operations using 5, 10 and 20 MHz channel spacing
- TVWS
  - TVWS network operates in VHF/UHF band.
  - The center frequencies are fixed and specified for each TV channel.
  - The band is not continuous.
  - Bandwidth of each TV channel is 6MHz in US and 7MHz or 8MHz in other area.

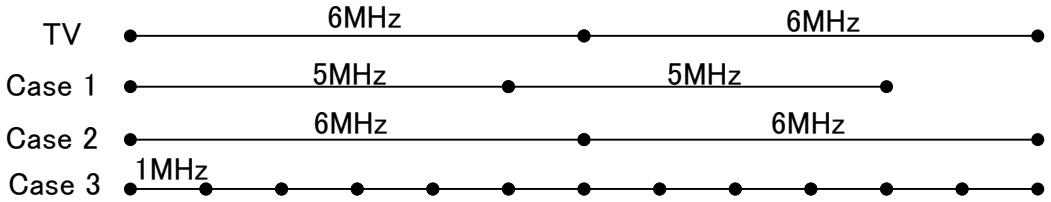
Topics of consideration

– **Channelization possibilities**

1. To keep 5MHz channel partition;
   - Satisfy manufactures
   - Simplify the implementation
2. To use channelization in TVWS bands (6, 7 and 8 MHz) , by changing related parameters in IEEE 802.11, such as sampling rate, transmit spectrum mask, FFT size, number of data subcarriers, etc.
   - Better use of available band
3. To have a different channel partition (1 MHz or 2 MHz), which can be applied to most regulatory domains.
   - Better use of available band.
   - Satisfy different regulatory classes

– PHY parameters

– Possible range of the system which effects the delay spread and therefore PHY parameters.



Comparison of Channel/System Properties

	802.22 (WRAN)		802.16e (WMAN)	802.11 (WLAN)
Coverage	**Typ.** 17 to 33 kms	**Max.** up to 100 kms	10 to 20 kms	up to few 100 m
Ch. (Max Delay spread)	11 to 25 us	25 to 60 us	10 to 20 us	100ns
FFT Size	2048		128, 512, 1024, 2048	64
Total BW (MHz)	6, 7, 8		1.25 (for 128) 5 (for 512) 10 (for 1024) 20 (for 2048)	5, 10, 20 ?
T_FFT (us)	299 (6 MHz), 256 (7 MHz), 224 (8 MHz)		91.4 us	12.8 for 5 MHz 6.4 for 10MHz 3.2 for 20 MHz
Guard Interval Duration	1/32, 1/16, 1/8, ¼		1/32, 1/16, 1/8, ¼	¼
Subcarrier spacing (KHz)	3.35 for 6MHz 3.91 for 7MHz 4.46 for 8MHz (no mobility)		10.94 (supports delay spread up to 20 us, mobility up to 125 km/h)	78 for 5 MHz 156 for 10MHz 312 for 64 FFT, 20 MHz

Expected Channel parameters for 802.11af

Indoor Models (IM)						
Range	LOS/NLOS	Paths	Max delay (-30 dB)	RMS delay T_rms	Coh. BW (0.5) = 1/(5*T_rms)	Coh. BW (0.9) = 1/(50*T_rms)
< 30 m	Yes	6 to 12	300 ns	50 ns	4 MHz	400KHz
30 to 100m	Yes	12 to 20	1 us	100 ns	2 MHz	200KHz

Outdoor Models (OM)						
Range	LOS/NLOS	Paths	Max delay (-30 dB)	RMS delay T_rms	Coh. BW (0.5) = 1/(5*T_rms)	Coh. BW (0.9) = 1/(50*T_rms)
< 500 m	-	2 to 4	2 us	0.4 us	500 KHz	50KHz
0.5 to 2 km	-	3 to 6	6 us	1 us	200 KHz	20 KHz
2 to 5 km	-	3 to 6	10 us	3 us	67 KHz	6.7 KHz

TVWS vs. 5GHz channel

- **Comparing with 5GHz channel of IEEE 802.11, the following channel parameters may change (supposing in the same scenario)**
  - Pathloss (smaller)
  - Number of multiple paths (more)
  - Delay spread (bigger)
  - Coherent bandwidth (smaller)
  - Doppler frequency (lower, Max 5.3 Hz ~ 64.4 Hz@at 100km/h)
  - Coherent time (larger)
- **Keep in mind**
  - The larger the subcarrier spacing, the less the useful symbol duration.
  - Increasing subcarrier spacing provides higher robustness against Doppler frequency, but more vulnerable to the frequency selectivity.

FFT size

- In frequency domain, the coherence bandwidth may be smaller than the subchannel spacing, resulting frequency selectivity within a subchannel.

Expected Indoor Models (IM)		
Range	CB(0.5)	CB(0.9)
< 30 m	4 MHz	400KHz
30 to 100m	2 MHz	200KHz

Expected Outdoor Models (OM)		
Range	CB(0.5)	CB(0.9)
< 500 m	500 KHz	50KHz
0.5 to 2 km	200 KHz	20 KHz
2 to 5 km	67 KHz	6.7 KHz

Bandwidth	Subcarrier Spacing		
	FFT size 64	FFT size 128	FFT size 256
5MHz	78KHz	39KHz	19.5KHz
10MHz	156KHz	78KHz	39KHz
20MHz	312KHz	156KHz	78KHz

Guard Interval (GI) Duration

Expected Indoor Models (IM)		
Range	Max delay (-30 dB)	RMS delay T_rms
< 30 m	300 ns	50 ns
30 to 100m	1 us	100 ns

Expected Outdoor Models (OM)		
Range	Max delay (-30 dB)	RMS delay T_rms
< 500 m	2 us	0.4 us
0.5 to 2 km	6 us	1 us
2 to 5 km	10 us	3 us

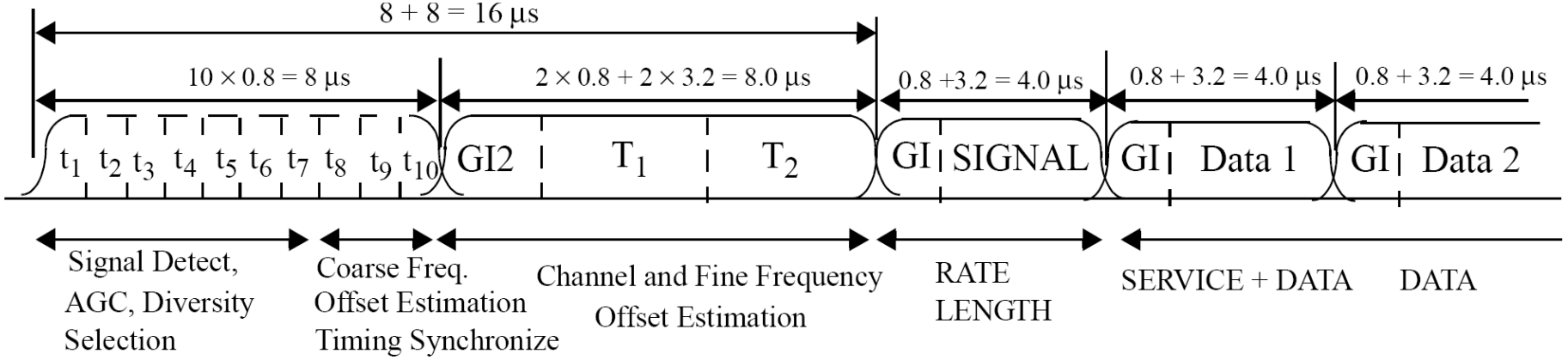
- If we keep the GI duration unchanged, the duration of GI may be smaller than the maximum delay , which results in inter symbol interference;
- If we simply increase GI duration without increasing FFT size, we may lose spectrum efficiency, therefore the GI duration shall be proportionally increased with FFT size .

Bandwidth	GI duration (1/4 FFT size)		
	FFT size 64	FFT size 128	FFT size 256
5MHz	3.2 us	6.4 us	12.8us
10MHz	1.6 us	3.2 us	6.4us
20MHz	0.8 us	1.6 us	3.2us

Preamble

- The PLCP preamble is a **time domain sequence** composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, time acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver)

Expected Outdoor Models (OM)		
Range	Max delay (-30 dB)	RMS delay T_rms
< 500 m	2 us	0.4 us
0.5 to 2 KM	6 us	1 us
2 to 5 K M	10 us	3 us



Note that to determine the optimal length channel estimation sequence, we need to take into account channel properties . We need to confirm it.

Pilot

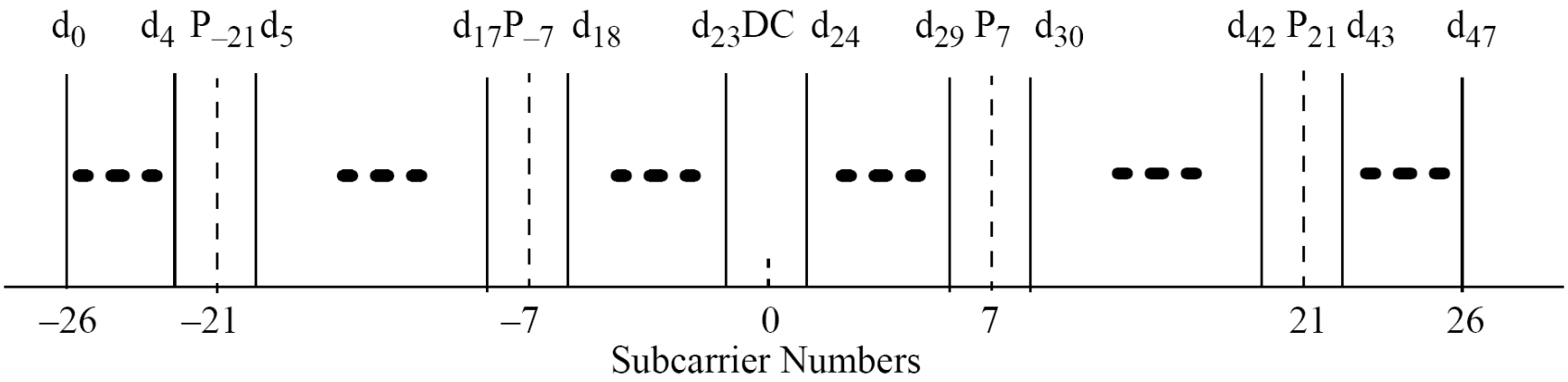


Figure 17-11—Subcarrier frequency allocation

- In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral line

Time selectivity is not a big problem. However due to lower Doppler frequency, and therefore higher coherence time, we may not have to insert pilot in each OFDM symbol, the spectrum efficiency may be potentially improved.

Conclusion

- Channelization is worthy of consideration in the group: (1) To partition the current spectrum into 5MHz channel; (2) To keep the current channelization in TVWS band. (3) To have a small channel partition of 1MHz or 2MHz.
- FFT size of 64 could be too small for 20 MHz BW and still small for 5 MHz BW in some cases
  - The GI duration cannot accommodate the channel response
  - Sub-carrier spacing may become too-wide and possibly more than the coherence BW of the channel, especially, in NLOS in the range > 1KM
- Consideration of FFT size of at least 128 could be necessary for outdoor environment.
- Time selectivity (around 100 ms) may not be a big problem.
- We shall confirm whether the length of preamble is long enough for channel estimation.

References

- **IEEE 802.22-05/55r7**
- **IEEE 802.16.3a-03/01**
- **IEEE 802.11-2007**
- **IEEE 802.19-09/0078r5**

Regulatory example of IEEE 802.11 in United States

Table J.1—Regulatory classes for 4.9 GHz and 5 GHz bands in the United States

Regulatory class	Channel starting frequency (GHz)	Channel spacing (MHz)	Channel set	Transmit power limit (mW)	Emissions limits set	Behavior limits set
1	5	20	36, 40, 44, 48	40	1	1, 2
2	5	20	52, 56, 60, 64	200	1	1
3	5	20	149, 153, 157, 161	800	1	1
4	5	20	100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140	200	1	1
5	5	20	165	1000	4	1
6	4.9375	5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	25	5	9
7	4.9375	5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	500	5	9
8	4.89	10	11, 13, 15, 17, 19	50	5	9
9	4.89	10	11, 13, 15, 17, 19	1000	5	9
10	4.85	20	21, 25	100	5	9
11	4.85	20	21, 25	2000	5	9
12–255	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

Regulatory example of TVWS in United States (from IEEE 802.22 Annex A)

Table 300 — Frequency of TV channels in North America (BW= 6 MHz)

Channel	Center Frequency	Channel	Center Frequency	Channel	Center Frequency
2	57	22	521	42	641
3	63	23	527	43	647
4	69	24	533	44	653
5	79	25	539	45	659
6	85	26	545	46	665
7	177	27	551	47	671
8	183	28	557	48	677
9	189	29	563	49	683
10	195	30	569	50	689
11	201	31	575	51	695
12	207	32	581	52	701
13	213	33	587	53	707
14	473	34	593	54	713
15	479	35	599	55	719
16	485	36	605	56	725
17	491	37	611	57	731
18	497	38	617	58	737
19	503	39	623	59	743
20	509	40	629		
21	515	41	635		