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Parameters for 802.16h support in different regulatory bands

Mariana Goldhamer (Alvarion)

Introduction

In the July meeting was identified the need for identifying the regulatory domains and a minimum set of parameters, as chanelization. This document provides a template and data for a number of bands to provide those elements, as well as a reduction of the number of possibilities within the interference-free sub-frame approach..

Discussion

In order to make sure that the MAC Frame synchronization, as basic element in the TDD interference reduction is ensured, shall be defined the MAC Frame duration and the Tx/Rx splitting for the targeted regulatory domains. The selection of the MAC Frame duration is affected by a number of parameters:

- The delay generated by in the operation of non-interfering elements, when using the ARQ
- The ability to support three different systems with type 1 or type 2 sub-frames
- FFT size suitable to the used frequency and the allowed powers (affecting the multi-path).

In order to find the suitable values an analysis was done of the common sub-frame durations for three regulatory cases: 5GHz, 3.65GHz and below 1 GHz, for different options of the standard, in relation to the different OFDM and OFDMA modes. The slot duration in OFDMA mode, based on channel spacing and no. of symbols in a slot, is very important in establishing the different options of the 802.16h. For example, the 2k FFT in 6MHz channel, which may be suitable for frequencies below 1GHz, may conduct to a need for longer frame sizes, introducing a very high delay.

FFT sizes and their options

In continuation are presented the assumptions on the FFT sizes for different regulatory domains. The possibility A includes all the possible OFDMA modes, having up to 6 symbols per slot. The possibility B drops the eventuality of 6 symbols per slot, using up to 2 symbols in DL and 3 symbols in UL.

The calculation of the PHY parameters for the regulatory domains of 5GHz, 3.65GHz and below 1GHz are shown below in Table 1 for 5GHz, Table 2 for 3.65GHz, Table 3 for <800MHz.

Table 1: 5GHz extended PHY parameters

Regulatory domain	5GHz								
Channel width (MHz)	5	5	10	10	10	20	20	20	20
Fft size	256	512	256	512	1024	256	512	1024	2048
Sampling factor	1.152	1.12	1.152	1.12	1.12	1.152	1.12	1.12	1.12
Sampling frequency	5.76	5.6	11.52	11.2	11.2	23.04	22.4	22.4	22.4
Symbol duration (us)	44.44444	91.42857	22.22222	45.71429	91.42857	11.11111	22.85714	45.71429	91.42857
Guard (cyclic prefix) duration	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
symbol + guard time duration (us)	50.000	102.857	25.000	51.429	102.857	12.500	25.714	51.429	102.857
Min. number of symbols for preamble, FCH, DL MAP	4	5	5	5	4	5	5	5	5
Min. duration of slots for MAP transmission	200	514.2857	125	257.1429	411.4286	62.5	128.5714	257.1429	514.2857
Max slot duration in Common sub-frame	0	514.2857	0	0	0	0	0	0	514.2857
Possibility A									
Max Symbols in DL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max Symbols in UL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max slot duration in DL	100	617.1429	150	308.5714	205.7143	75	154.2857	308.5714	617.1429
Max slot duration over all modes in DL	0	617.1429	0	0	0	0	0	0	617.1429
Max slot duration in UL	100	617.1429	150	308.5714	205.7143	75	154.2857	308.5714	617.1429
Max slot duration over all modes in UL	0	617.1429	0	0	0	0	0	0	617.1429
Possibility B									
Max Symbols in DL OFDMA PHY slot	2	2	2	2	2	2	2	2	2
Max Symbols in UL OFDMA PHY slot	2	3	3	3	2	3	3	3	3
Max slot duration in DL	100	205.7143	50	102.8571	205.7143	25	51.42857	102.8571	205.7143
Max slot duration over all modes in UL	0	205.7143	0	0	205.7143	0	0	0	205.7143
Max slot duration in UL	100	308.5714	75	154.2857	205.7143	37.5	77.14286	154.2857	308.5714
Max slot duration over all modes in UL	0	308.5714	0	0	0	0	0	0	308.5714

Table 2: 3.65GHz extended PHY parameters

Regulatory domain	3.65GHz								
Channel width (MHz)	7	7	7	10	10	10	14	14	14
Fft size	256	512	1024	256	512	1028	512	1024	2048
Sampling factor	1.152	1.12	1.12	1.152	1.12	1.12	1.12	1.12	1.12
Sampling frequency	8.064	7.84	7.84	11.52	11.2	11.2	15.68	15.68	15.68
Symbol duration (us)	31.74603	65.30612	130.6122	22.22222	45.71429	91.78571	32.65306	65.30612	130.6122
Guard (cyclic prefix) duration	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
symbol + guard time duration (us)	35.714	73.469	146.939	25.000	51.429	103.259	36.735	73.469	146.939
Min. number of symbols for preamble, FCH, DL MAP	4	5	5	5	4	5	5	5	5
Min. duration of slots for MAP transmission	142.8571	367.3469	734.6939	125	205.7143	516.2946	183.6735	367.3469	734.6939
Max slot duration in Common sub-frame	0	0	734.6939	0	0	0	0	0	734.6939
Possibility A									
Max Symbols in DL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max Symbols in UL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max slot duration in DL	71.42857	440.8163	881.6327	150	102.8571	619.5536	220.4082	440.8163	881.6327
Max slot duration over all modes in DL	0	0	881.6327	0	0	0	0	0	881.6327
Max slot duration in UL	71.42857	440.8163	881.6327	150	102.8571	619.5536	220.4082	440.8163	881.6327
Max slot duration over all modes in UL	0	0	881.6327	0	0	0	0	0	881.6327
Possibility B									
Max Symbols in DL OFDMA PHY slot	2	2	2	2	2	2	2	2	2
Max Symbols in UL OFDMA PHY slot	2	3	3	3	2	3	3	3	3
Max slot duration in DL	71.42857	146.9388	293.8776	50	102.8571	206.5179	73.46939	146.9388	293.8776
Max slot duration over all modes in UL	0	0	293.8776	0	0	0	0	0	293.8776
Max slot duration in UL	71.42857	220.4082	440.8163	75	102.8571	309.7768	110.2041	220.4082	440.8163
Max slot duration over all modes in UL	0	0	440.8163	0	0	0	0	0	440.8163

Table 3: 450-800MHz extended PHY parameters

Regulatory domain	450-800MHz								
Channel width (MHz)	6	6	6	6	7	7	7	7	8
Fft size	256	512	1024	2048	256	512	1024	2048	2048
Sampling factor	1.146667	1.12	1.12	1.12	1.142857	1.142857	1.142857	1.142857	1.12
Sampling frequency	6.88	6.72	6.72	6.72	8	8	8	8	8.96
Symbol duration (us)	37.2093	76.19048	152.381	304.7619	32	64	128	256	228.5714
Guard (cyclic prefix) duration	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
symbol + guard time duration (us)	41.860	85.714	171.429	342.857	36.000	72.000	144.000	288.000	257.143
Min. number of symbols for preamble, FCH, DL MAP	4	5	5	5	4	5	5	5	5
Min. duration of slots for MAP transmission	167.4419	428.5714	857.1429	1714.286	144	360	720	1440	1285.714
Max slot duration in Common sub-frame	0	0	0	1714.286	0	0	0	0	0
Possibility A									
Max Symbols in DL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max Symbols in UL OFDMA PHY slot	2	6	6	6	2	6	6	6	6
Max slot duration in DL	83.72093	514.2857	1028.571	2057.143	72	432	864	1728	1542.857
Max slot duration over all modes in DL	0	0	0	2057.143	0	0	0	0	0
Max slot duration in UL	83.72093	514.2857	1028.571	2057.143	72	432	864	1728	1542.857
Max slot duration over all modes in UL	0	0	0	2057.143	0	0	0	0	0
Possibility B									
Max Symbols in DL OFDMA PHY slot	2	2	2	2	2	2	2	2	2
Max Symbols in UL OFDMA PHY slot	2	3	3	3	2	3	3	3	3
Max slot duration in DL	83.72093	171.4286	342.8571	685.7143	72	144	288	576	514.2857
Max slot duration over all modes in UL	0	0	0	685.7143	0	0	0	0	0
Max slot duration in UL	83.72093	257.1429	514.2857	1028.571	72	216	432	864	771.4286
Max slot duration over all modes in UL	0	0	0	1028.571	0	0	0	0	0

Based on the max. slot durations calculated above, was made a sanity check of the sub-frame durations for the two existing types.
Was also calculated the maximum delay in ARQ process, with the assumption that a system operating as Master and having limited interference will have a low probability of re-transmission.

Table 4: Sanity check for the extended PHY parameters

	5GHz	**3.65GHz**	**<1GHz**	**5GHz**	**3.65GHz**	**<1GHz**	**5GHz**	**3.65GHz**	**<1GHz**
MAC Frame duration (ms)	5000	5000	5000	10000	10000	10000	20000	20000	20000
Percentage of DL	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Duration of DL	3000	3000	3000	6000	6000	6000	12000	12000	12000
Duration of UL	2000	2000	2000	4000	4000	4000	8000	8000	8000
Control slot	2000	2000	2000	2000	2000	2000	2000	2000	2000
Common sub-frame with type 1	750	750	750	1500	1500	1800	3000	3000	3000
Common sub-frame with type 2	1000	1000	1000	3000	3000	3000	6000	6000	6000
DL Master sub_frame with type 1	750	750	750	1500	1500	1400	3000	3000	3000
DL Master sub_frame with type 2	2000	2000	2000	3000	3000	3000	6000	6000	6000
Sanity check for common sub-frame with type 1	ok	ok	FALSE	ok	ok	ok	ok	ok	ok
Sanity check for common sub-frame with type 2	ok	ok	FALSE	ok	ok	ok	ok	ok	ok
Min. duration of common sub-frame	514.2857	734.6939	1714.286	514.2857	734.6939	1714.286	514.2857	734.6939	1714.286
Max. slot duration in DL, poss A	617.1429	881.6327	2057.143	617.1429	881.6327	2057.143	617.1429	881.6327	2057.143
Max. slot duration in DL, poss B	205.7143	293.8776	685.7143	205.7143	293.8776	685.7143	205.7143	293.8776	685.7143
Max. slot duration in UL, poss A	617.1429	881.6327	2057.143	617.1429	881.6327	2057.143	617.1429	881.6327	2057.143
Max. slot duration in UL, poss B	308.5714	440.8163	1028.571	308.5714	440.8163	1028.571	308.5714	440.8163	1028.571
Slots/sub-frame, DL	5	5	5	5	5	5	5	5	5
Slots/sub-frame, UL	4	4	4	4	4	4	4	4	4
Sub-frame duration, poss A, DL	3085.714	4408.163	10285.71	3085.714	4408.163	10285.71	3085.714	4408.163	10285.71
Sub-frame duration, poss B, DL	1028.571	1469.388	3428.571	1028.571	1469.388	3428.571	1028.571	1469.388	3428.571
Sub-frame duration, poss A, UL	2468.571	3526.531	8228.571	2468.571	3526.531	8228.571	2468.571	3526.531	8228.571
Sub-frame duration, poss B, UL	1234.286	1763.265	4114.286	1234.286	1763.265	4114.286	1234.286	1763.265	4114.286
Sanity check for control slot with type 1(DL-	ok	ok	FALSE	ok	ok	ok	ok	ok	ok

Controlslot>common)									
Max. delay for type 1, 3 masters + 1 common	12500	12500	12500	25000	25000	25000	50000	50000	50000
Sanity check for Type 1, poss A, 3Masters (DL-common > 3*subframe)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Sanity check for Type 1, poss B, 3Masters (DL-common > 3*subframe)	FALSE	FALSE	FALSE	ok	ok	FALSE	ok	ok	FALSE
Sanity check for Type 1, poss A, 3Masters (UL > 3*subframe)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	ok	FALSE	FALSE
Sanity check for Type 1, poss B, 3Masters (UL > 3*subframe)	FALSE	FALSE	FALSE	ok	FALSE	FALSE	ok	ok	FALSE
Max. delay for type 2, 3 masters + 1 common	25000	25000	25000	50000	50000	50000	100000	100000	100000
Sanity check for Type 2, poss A (DL-common > sub-frame)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	ok	ok	FALSE
Sanity check for Type 2, poss B (DL-common > sub-frame)	ok	ok	FALSE	ok	ok	FALSE	ok	ok	ok
Sanity check for Type 2, poss A (UL > sub-frame)	FALSE	FALSE	FALSE	ok	FALSE	FALSE	ok	ok	FALSE
Sanity check for Type 2, poss B (UL > sub-frame)	ok	ok	FALSE	ok	ok	FALSE	ok	ok	ok

Has resulted that the 5ms MAC frames, best suitable to ARQ and reasonable delays, are not usable with high FFT sizes.
In next attempt was avoided the highest FFT size in every regulatory domain. The results of the sanity check for the resulting restricted usage mode is presented below.

Table 5: Sanity check for the restricted FFT sizes

v	**5GHz**	**3.65GHz**	**<1GHz**	**5GHz**	**3.65GHz**	**<1GHz**	**5GHz**	**3.65GHz**	**<1GHz**
MAC Frame duration (ms)	5000	5000	5000	10000	10000	10000	20000	20000	20000
Percentage of DL	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Duration of DL	3000	3000	3000	6000	6000	6000	12000	12000	12000
Duration of UL	2000	2000	2000	4000	4000	4000	8000	8000	8000
Control slot	2000	2000	2000	2000	2000	2000	2000	2000	2000
Common sub-frame with type 1	750	750	750	1500	1500	1800	3000	3000	3000
Common sub-frame with type 2	1000	1000	1000	3000	3000	3000	6000	6000	6000
DL Master sub_frame with type 1	750	750	750	1500	1500	1400	3000	3000	3000
DL Master sub_frame with type 2	2000	2000	2000	3000	3000	3000	6000	6000	6000
Sanity check for common sub-frame with type 1	ok	ok	FALSE	ok	ok	ok	ok	ok	ok
Sanity check for common sub-frame with type 2	ok	ok	ok	ok	ok	ok	ok	ok	ok

Min. duration of common sub-frame	257.1429	516.2946	857.1429	257.1429	516.2946	857.1429	257.1429	516.2946	857.1429
Max. slot duration in DL, poss A	308.5714	619.5536	1028.571	308.5714	619.5536	1028.571	308.5714	619.5536	1028.571
Max. slot duration in DL, poss B	102.8571	206.5179	342.8571	102.8571	206.5179	342.8571	102.8571	206.5179	342.8571
Max. slot duration in UL, poss A	308.5714	619.5536	1028.571	308.5714	619.5536	1028.571	308.5714	619.5536	1028.571
Max. slot duration in UL, poss B	154.2857	309.7768	514.2857	154.2857	309.7768	514.2857	154.2857	309.7768	514.2857
Slots/sub-frame, DL	4	4	4	4	4	4	4	4	4
Slots/sub-frame, UL	4	4	4	4	4	4	4	4	4
Sub-frame duration for the above slots, poss A, DL	1234.286	2478.214	4114.286	1234.286	2478.214	4114.286	1234.286	2478.214	4114.286
Sub-frame duration, poss B, DL	411.4286	826.0714	1371.429	411.4286	826.0714	1371.429	411.4286	826.0714	1371.429
Sub-frame duration, poss A, UL	1234.286	2478.214	4114.286	1234.286	2478.214	4114.286	1234.286	2478.214	4114.286
Sub-frame duration, poss B, UL	617.1429	1239.107	2057.143	617.1429	1239.107	2057.143	617.1429	1239.107	2057.143
Sanity check for control slot (DL-Controlslot>common)	ok	ok	ok	ok	ok	ok	ok	ok	ok
Max. delay for type 1, 3 masters + 1 common	12500	12500	12500	25000	25000	25000	50000	50000	50000
Sanity check for Type 1, poss A, 3Masters (DL-common > 3*subframe)	FALSE	FALSE	FALSE	ok	FALSE	FALSE	ok	ok	FALSE
Sanity check for Type 1, poss B, 3Masters (DL-common > 3*subframe)	ok	FALSE	FALSE	ok	ok	ok	ok	ok	ok
Sanity check for Type 1, poss A, 3Masters (UL > 3*subframe)	FALSE	FALSE	FALSE	ok	FALSE	FALSE	ok	ok	FALSE
Sanity check for Type 1, poss B, 3Masters (UL > 3*subframe)	ok	FALSE	FALSE	ok	ok	FALSE	ok	ok	ok
Max. delay for type 2, 3 masters + 1 common	25000	25000	25000	50000	50000	50000	100000	100000	100000
Sanity check for Type 2, poss A (DL-common > sub-frame)	ok	FALSE	FALSE	ok	ok	FALSE	ok	ok	ok
Sanity check for Type 2, poss B (DL-common > sub-frame)	ok	ok	ok	ok	ok	ok	ok	ok	ok
Sanity check for Type 2, poss A (UL > sub-frame)	ok	FALSE	FALSE	ok	ok	FALSE	ok	ok	ok
Sanity check for Type 2, poss B (UL > sub-frame)	ok	ok	FALSE	ok	ok	ok	ok	ok	ok

The conclusions are:

1. Type 2 is easier to implement and may be more technology neutral; however also other aspects should be checked, as min. length of the MAP and the suitability of very short common intervals with type 2.
2. Due to the fact that all the common parts with type 2 are used for the start of frame and MAP transmission, not allowing time for the data transmission, a common MAC frame should be added to the existing type 2. This will increase the min. time which can be allocated to a system, especially in the case of 5ms MAC Frames.
3 The number of Master systems at a time shall be limited to 3, otherwise the delays will be too high.
4. The suitable MAC Frame durations are:
   - 5ms for 5GHz
   - for this moment in time, keep both 5ms and 10ms for 3.65GHz, because the 10ms will allow higher FFTs
   - 10ms for <1GHz (20ms may be more suitable, but the delays will not be acceptable)
   - The number of equations describing the sub-frame durations (15.4.2.1.2) may be reduced; it is preffered the form with a given value for the common part. The given value will depend on the MAC duration and the regulatory domain.

Proposed text changes

1. Modifications to the text in 15.4.2.1.2

For type 1:

~~$T_{Tx\_sub\text{-}frame} = T_{TxMAC} / (N+1)$~~

~~or~~

— $T_{Tx\_sub\text{-}frame} = (T_{TxMAC} - ~~T_{Txsh}~~ T_{TxC}) / N$

~~$T_{Rx\_sub\text{-}frame} = T_{RxMAC} / (N+1)$~~

~~or~~

— $T_{Rx\_sub\text{-}frame} = (T_{RxMAC} - ~~T_{Rxsh}~~ T_{RxC}) / N$

For type 2:

~~$T_{Tx\_sub\text{-}frame} = T_{TxMAC} / 2$~~

~~or~~

— $T_{Tx\_sub\text{-}frame} = T_{TxMAC} - ~~T_{Txsh}~~ T_{TxC}$

~~$T_{Rx\_sub\text{-}frame} = T_{RxMAC} / 2$~~

~~or~~

— $T_{Rx\_sub\text{-}frame} = T_{RxMAC} - ~~T_{Rxsh}~~ T_{RxC}$

and the repetition interval RI equals to either $N*T_{MAC}$ or $(N+1)*T_{MAC}$. In the last case the repetitive sequence starts with a Common MAC Frame.

$N_{MAX} = 3$.

2. New chapter 15.6

Insert a new Chapter 15.6 (before the existing 15.6)

15.6 Relevant regulatory domains

The procedures described in chap. 15 may be used in a high variety of regulatory scenarios.

In this chapter we identify some essential requirements, as chanelization and MAC Frame durations, to be used in a sample list of regulatory domains. Supplementary it is indicated that may be a need for FFT size limitation.

Table XX Relevant regulatory domains and essential CX parameters

Regulatory Index	Frequency band	Regulatory authority	Channel Spacing (MHz)	Channel centers (MHz)	CXZ Parameters	Recommendations

1	5.25 – 5.875GHz	FCC, ECC	10, 20	See chap. 8.5	MAC Frame duration: 5ms, RI=20ms Sub-frame type: 2 DL Common sub-frame: 1ms	FFT sizes : up to 1k
2	3.65 – 3.7GHz	FCC	7	3654, 3661, 3.668 *3.675*,3682,3689,3696	MAC Frame duration: 5ms, 10ms? RI=20ms, 30ms? Sub-frame type: 2? DL Common sub-frame: 1ms, 3ms?	FFT sizes : up to 512
2	3.65 – 3.7GHz (BWA)	FCC	20	3661, 3689	Idem	FFT sizes : up to 1k
3	< 850MHz (TV Bands)	FCC	6	Centers of the TV channels	MAC Frame duration: 10ms Sub-frame type: 2? DL Common sub-frame: 3ms?	FFT sizes: up to 1k
4	4.940-4990GHz (Public Safety)	FCC (03-99)	5	4942.5 +n*5MHz	MAC Frame duration: 5ms, RI=20ms Sub-frame type: 2 DL Common sub-frame: 1ms	FFT sizes : up to 512
4	4.940-4990GHz	FCC	10	4950, 4960, 4970, 4980, 4990	Idem	FFT sizes : up to 1k
4	4.940-4990GHz	FCC	20	4955, 4975	Idem	FFT sizes : up to 1k