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Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)
Title	**Channel Model Parameterization of the Indoor Residential Environment**
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Re:	[Response to Call for Contributions on 15.4a Channel Modeling Subgroup.]
Abstract	[This document summarizes the important channel parameters reported in the literature based on the UWB channel measurements in indoor residential environment.]
Purpose	
Notice	
Release	

I. INTRODUCTION

The aim of this document is to summarize the important channel parameters reported in the literature based on the UWB channel measurements in indoor residential environment.

II. PATH LOSS AND SHADOWING

The path loss in dB as a function distance is given by

$$PL(d) = PL_0 + 10n\log_{10}\left(\frac{d}{d_0}\right) + S; \quad d \geq d_0 \tag{1}$$

where d_0 is the reference distance i.e. $d_0 = 1m$ and PL_0 is the free-space path loss in the far-field of the antennas at a reference distance d_0. PL_0 is the interception point and usually is calculated based on the mid-band frequency. n is the path loss exponent and S is the shadowing fading parameter that varies randomly from one location to another location within any home. It is a zero-mean Gaussian distributed random variables (in dB) with standard deviation σ_S which is also in dB. Table 1 list the path loss and shadowing parameters extracted from the measurement data. Note that, unless otherwise stated, μ and σ represent the mean and standard deviation of the corresponding parameter. For example, μ_n and σ_n represent the mean and standard deviation of the path loss exponent, respectively.

III. TEMPORAL DOMAIN PARAMETERS

The *mean excess delay,* τ_m is defined as the first moment of the power delay profile (PDP) and is defined as [1]

$$\tau_m = \frac{\sum_k a_k^2 \tau_k}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \tag{2}$$

where a_k , τ_k and $P(\tau_k)$ are the gain coefficient, delay and PDP of the k^{th} multipath component (MPC), respectively. The *rms delay spread,* τ_{rms} is the square root of the second central moment of the PDP and is defined to be [1]

$$\tau_{rms} = \sqrt{\tau_m^2 - (\tau_m)^2} \tag{3}$$

where

$$\tau_m^2 = \frac{\sum_k a_k^2 \tau_k^2}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)\tau_k^2}{\sum_k P(\tau_k)}. \quad (4)$$

$NP10dB$ is defined as the number of MPCs that arrive within 10 dB of the strongest path for each of the PDP. Table 2 list the temporal domain parameters extracted from the measurement data.

IV. Saleh-Valenzuela Multipath Channel Parameters

The main structure of the IEEE 802.15.4a multipath channel model is detailed in [2] and will be based on the conventional Saleh-Valenzuela (S-V) clustering channel model [3]. As described in Section III of [4], there are 5 key parameters that define the S-V multipath channel model:

- Λ is the cluster arrival rate
- λ is the ray arrival rate, i.e. the arrival rate of path within each cluster
- Γ is the cluster exponential decay factor
- γ is the ray exponential decay factor
- σ_a is the standard deviation of the lognormal fading term (dB).

Table 3 list the S-V multipath channel parameters extracted from the measurement data.

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Source	LOS					NLOS				
	n		PL_0 [dB]	S [dB]		n		PL_0 [dB]	S [dB]	
AT&T [5]-[7]	μ_n	σ_n	47.0	μ_S	σ_S	μ_n	σ_n	51.0	μ_n	σ_n
	1.70	0.30		1.60	0.50	3.50	0.97		2.70	0.98
AT&T [8]	μ_n	σ_n	47.2	μ_S	σ_S	μ_n	σ_n	50.4	μ_n	σ_n
	1.82	0.39		1.50	0.60	3.34	0.73		2.60	0.90
	2.01		45.9	3.20		3.12		50.3	3.80	
CEA-LETI [9]	1.67		-	-		4.97[1]		-	-	
						7.24[2]				
Intel [10]	1.72		-	1.48		4.09		-	3.63	
Samsung/SAIT [11]	1.18[3]		50.1[3]	0.93[3]		2.18[3]		52.2[3]	1.43[3]	
	2.48[4]		49.7[4]	1.50[4]		2.69[4]		52.7[4]	4.69[4]	
U.C.A.N [12], [13]	1.67		-	4.0		5.13[1]		-	4.0	
						7.25[2]				

Table 1: Path loss and shadowing parameters.

Source	LOS						NLOS					
	τ_m, [ns]		τ_{rms}, [ns]		$NP10dB$		τ_m, [ns]		τ_{rms}, [ns]		$NP10dB$	
	μ_{τ_m}	σ_{τ_m}	$\mu_{\tau_{rms}}$	$\sigma_{\tau_{rms}}$	μ_{NP10dB}	σ_{NP10dB}	μ_{τ_m}	σ_{τ_m}	$\mu_{\tau_{rms}}$	$\sigma_{\tau_{rms}}$	μ_{NP10dB}	σ_{NP10dB}
AT&T [7]	-	-	-	-	-	-	10.83[5]		8.43[5]		60[5]	
							12.40[6]		11.5[6]		82[6]	
AT&T [7], [14]	-	-	4.70[7]	2.30[7]	-	-	-	-	8.20[7]	3.30[7]	-	-
AT&T [15]	2.15	-	3.55	1.65	-	-	6.93	-	7.35	3.45	-	-
CEA-LETI [9]	6.53	-	11.45	-	3.4	-	-	-	-	-	-	-
Intel [16]	4.01	-	8.88	-	7	-	17.36	-	14.53	-	35	-
Intel [10], [16]	3.06[8]	-	7.39[8]	-	6[8]	5	9.96[8]	-	12.81[8]	-	28[8]	30
	3.09[9]		7.93[9]		6[9]		10.06[9]		13.22[9]		29[9]	
	4.01[10]		8.88[10]		7[10]		17.36[10]		14.53[10]		36[10]	
	3.95[11]		9.13[11]		7[11]		17.25[11]		15.0[11]		37[11]	
Samsung/SAIT [11]	5.88[3]	1.25[3]	14.00[3]	1.53[3]	4.04[3]	1.53[3]	36.09[3]	15.48[3]	38.61[3]	8.03[3]	19.58[3]	7.64[3]
	5.01[4]	0.64[4]	12.48[4]	1.87[4]	5.97[4]	1.96[4]	24.95[4]	8.47[4]	26.51[4]	5.22[4]	23.51[4]	10.75[4]
Time Domain [17]	4.95	4.14	5.27	3.37	24.0	-	10.04[12]	6.26[12]	8.78[12]	4.34[12]	36.1[12]	-
							14.24[13]	5.97[13]	14.59[13]	3.41[13]	61.6[13]	
U.C.A.N [12], [13]	7.52	1.94	12.15	1.88	3.82	2.43	7.74[1]	2.27[1]	9.94[1]	1.52[1]	16.71[1]	9.44[1]
							14.48[2]	3.03[2]	12.94[2]	1.38[2]	31.27[2]	16.86[2]

Table 2: Temporal domain parameters.

Source	LOS					NLOS				
	Λ [1/ns]	λ [1/ns]	Γ [ns]	γ [ns]	σ_a [dB]	Λ [1/ns]	λ [1/ns]	Γ [ns]	γ [ns]	σ_a [dB]
CEA-LETI [9]	0.007	1.27	30	10	5.5-1.0[14]	-	-	-	-	-
Intel [16]	1/60	1/0.5	16	1.6	4.8	1/11	1/0.35	16	8.5	4.8
U.C.A.N [12], [13]	0.01	0.18	21	6	4	0.01[1]	3[1]	18[1]	5[1]	4[1]
						0.4[2]	1.5[2]	9[2]	8[2]	4[2]

Table 3: S-V multipath channel parameters.

[1] Analysis for 45 different TX-RX positions with distance between 9-13 m under NLOS scenario [9], [12], [13].
[2] Analysis for 109 different TX-RX positions with distance between 7-17 m under NLOS scenario [9], [12], [13].
[3] Analysis for 3-bedroom apartment [11].
[4] Analysis for 4-bedroom apartment [11].
[5] Analysis based on 30 dB threshold level for 50% of the NLOS locations [7].
[6] Analysis based on 30 dB threshold level for 90% of the NLOS locations [7].
[7] τ_{rms} is Gaussian distributed over all homes with mean, $\mu_{\tau_{rms}}$ and standard deviation, $\sigma_{\tau_{rms}}$ [7], [14].
[8] Analysis based on passband analysis, frequency domain Hamming windowing and 0.17 ns bin size [10].
[9] Analysis based on complex baseband analysis, frequency domain Hamming windowing and 0.17 ns bin size [10].
[10] Analysis based on passband analysis, frequency domain rectangular windowing and 0.17 ns bin size [10].
[11] Analysis based on complex baseband analysis, frequency domain rectangular windowing and 0.17 ns bin size [10].
[12] Analysis for TX-RX positions with distance between 0-4 m under NLOS scenario [17].
[13] Analysis for TX-RX positions with distance between 4-10 m under NLOS scenario [17].
[14] Decrease with delay [9].