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Re:	"Call for Comments on Draft 802.16m Evaluation Methodology Document Deadline: 3 May 2007 AOE" 2007-04-17, IEEE 802.16m-07/014r1		
Abstract	The document describes the proposed MIMO channel model approach and parameter values for IEEE 802.16m link-level and system-level simulations.		
Purpose	To be included entirely or partially in the evaluation documents (Draft IEEE 802.16m Evaluation Methodology Document, IEEE C802.16m-07/080r1).		
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MIMO CHANNEL MODEL APPROACH AND PARAMETERS FOR 802.16m

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1 Introduction

IEEE 802.16m is aiming towards IMT-Advanced with 1 Gbps peak data rate obtained by using wide bandwidth and multi-antenna technologies. It is therefore important to consider wide bandwidth, high data rate, multiple antennas as well as system aspects in channel modeling for 802.16m.

Radio propagation has a significant impact on the performance of wireless communication systems, therefore realistic channel models are needed during the system evaluation phase. The impact on future broadband systems is even more important than on currently existing systems. Because of the major influence on the system performance and complexity, radio channel models and simulations must be more versatile and accurate than in earlier systems. The more we know about the channel in different dimensions the better means we have for successful design and comparison between different wireless technologies.

This is especially true with future multiple-input multiple-output (MIMO) radio communication systems (Figure 1) since more of the radio channel degrees of freedom (space, time, frequency, and polarization) may be exploited to meet the demands on bit rate, spectrum efficiency and cost. The understanding of radio propagation is necessary when choosing modulation and coding, in antenna and antenna array design, selection of channel estimation method, channel equalization and other baseband algorithm design as well as network planning. It is important to use common and uniform channel models for evaluation, comparison and selection of technologies. In this context it is clear that realistic and reliable multidimensional channel models are important part of performance evaluation of IEEE 802.16m.

This contribution contains a description of the proposed modeling approach as well as parameter values for some selected scenarios. The proposed channel model is geometry-based, stochastic, antenna independent, and generic. It covers all dimensions including polarization. It is also possible to down-scale the model to reduce the randomness and complexity. This contribution is based on 7, 7, and 7.

2 Channel model approach for evaluations of proposed 802.16m air interface technologies

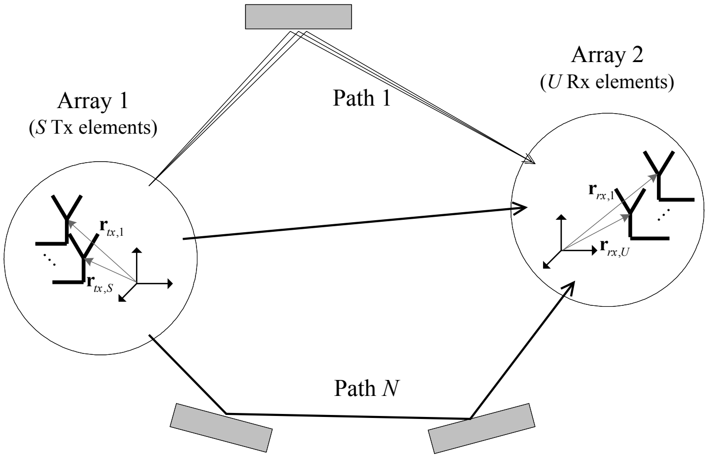
The proposed channel model is a geometry-based stochastic model. Geometric based modeling of the radio channel enables separation of propagation parameters and antennas.

The channel parameters for individual snapshots are determined stochastically, based on statistical distributions extracted from channel measurement. Antenna geometries and field patterns can be defined properly by the user of the model. Channel realizations are generated with geometrical principle by summing contributions of rays (plane waves) with specific small scale parameters like delay, power, angle-of-arrival (AoA) and angle-of-departure (AoD). Superposition results to correlation between antenna elements and temporal fading with geometry dependent Doppler spectrum.

A number of rays constitute a cluster. In the terminology of this document we equate the cluster with a propagation path diffused in space, either or both in delay and angle domains. Elements of the MIMO channel, i.e. antenna arrays at both link ends and propagation paths, are illustrated in Figure 1.

FIGURE 1

The MIMO channel



Transfer matrix of the MIMO channel is

$$\mathbf{H}(t;\tau) = \sum_{n=1}^{N} \mathbf{H}_n(t;\tau) \tag{1}$$

It is composed of antenna array response matrices $\mathbf{F}_{tx}$ for the transmitter, $\mathbf{F}_{rx}$ for the receiver and the propagation channel response matrix $\mathbf{h}_n$ for cluster n as follows

$$\mathbf{H}_n(t;\tau) = \iint \mathbf{F}_{rx}(\varphi)\mathbf{h}_n(t;\tau,\phi,\varphi)\mathbf{F}_{tx}^T(\phi)\, d\phi\, d\varphi \tag{2}$$

The channel from Tx antenna element s to Rx element u for cluster n is

$$H_{u,s,n}(t;\tau) = \sum_{m=1}^{M} \begin{bmatrix} F_{rx,u,V}(\phi_{n,m}) \\ F_{rx,u,H}(\phi_{n,m}) \end{bmatrix}^T \begin{bmatrix} \alpha_{n,m,VV} & \alpha_{n,m,VH} \\ \alpha_{n,m,HV} & a_{n,m,HH} \end{bmatrix} \begin{bmatrix} F_{tx,s,V}(\varphi_{n,m}) \\ F_{tx,s,H}(\varphi_{n,m}) \end{bmatrix} \times \exp\left(j2\pi\lambda_0^{-1}(\bar{\phi}_{n,m}\cdot\bar{r}_{rx,u})\right)\exp\left(j2\pi\lambda_0^{-1}(\bar{\varphi}_{n,m}\cdot\bar{r}_{tx,s})\right) \times \exp\left(j2\pi\upsilon_{n,m}t\right)\delta(\tau-\tau_{n,m}) \tag{3}$$

where $F_{rx,u,V}$ and $F_{rx,u,H}$ are the antenna element u field patterns for vertical and horizontal polarizations respectively, $\alpha_{n,m,VV}$ and $\alpha_{n,m,VH}$ are the complex gains of vertical-vertical and vertical-horizontal polarizations of ray n,m respectively. Further λ_0 is the wave length on carrier frequency, $\bar{\phi}_{n,m}$ is AoD unit vector, $\bar{\varphi}_{n,m}$ is AoA unit vector, $\bar{r}_{tx,s}$ and $\bar{r}_{rx,u}$ are the location vectors of element s and u respectively, and $\nu_{n,m}$ is the Doppler frequency component of ray n,m. If the radio channel is modeled as dynamic, all the above mentioned small scale parameters are time variant, i.e. function of t.

2.1 Primary Models

WINNER generic model is a system level model, which can describe an infinite number of propagation environment realizations. The generic model can describe single or multiple radio links for all the defined scenarios and arbitrary antenna configurations. This is done by applying different parameter sets to a single common mathematical framework. The generic model is a stochastic model with two (or three) levels of randomness. The first level, known as large scale (LS), parameters like Shadow fading, delay and angular spreads are drawn randomly from tabulated distribution functions. Next, the small scale parameters like delays, powers and directions arrival and departure are drawn randomly according to tabulated distribution functions and the random LS parameters (second moments). At this stage the geometric setup is fixed and the only free variables are the random initial phases of the scatterers. By picking (randomly) different initial phases, an infinite number of different realizations of the model can be generated. When the initial phases are also fixed, there is no further randomness.

2.2 Reduced Variability Models

Reduced variability models are derived from the primary model by fixing a set of its parameters. These simplified models should be applied only for calibration of simulation systems. The concept of clustered delay line (CDL) models is a spatial extension of tapped delay line (TDL) models. TDL models contain usually power, delay and Doppler spectrum information for the taps. CDL models define power, delay and angular information. Doppler is not explicitly defined, because it is determined by power and angular information combined with array characteristics.

3 Scenarios

The sub-sections below include several propagation scenarios. They have been categorized according to the four evaluation scenarios, namely indoor, microcellular, base coverage urban and high-speed vehicular. From each category, at least one propagation scenario should be selected.

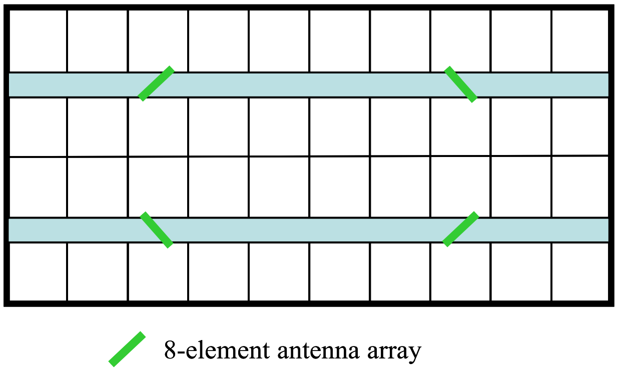
3.1 Indoor

3.1.1 A1 – Indoor small office

Scenario A1 environment represents typical office environment, where the area per floor is 5 000 m^2, number of floors is 3 and room dimensions are 10 m x 10 m x 3 m and the corridors have the dimensions 100 m x 5 m x 3 m. The layout of the scenario is shown in Figure 2.

FIGURE 2

Layout of the A1 indoor scenario



Rooms: 10 x 10 x 3 m
Corridors: 5 x 100 x 3 m

3.2 *Microcellular*

3.2.1 B4 – Outdoor to indoor

Outdoor environment is metropolitan area B1, typical urban microcell where the user density is typically high, and thus the requirements for system throughput and spectral efficiency are high. The corresponding indoor environment is A1, typical indoor small office. It is assumed that the floors 1 to 3 are used in simulations, floor 1 meaning the ground floor.

3.2.2 B1 – Urban micro-cell

In urban micro-cell scenarios the height of both the antenna at the BS and that at the MS is assumed to be well below the tops of surrounding buildings. Both antennas are assumed to be outdoors in an area where streets are laid out in a Manhattan-like grid. The streets in the coverage area are divided into three classifications. The first, classified as “the main street”, is a street with LOS from all locations to the BS. The “main street” LOS may also be temporarily blocked by traffic (e.g. trucks and busses) on the street. Streets that intersect the main street are referred to as perpendicular streets, and those that run parallel to it are referred to as parallel streets. This scenario is defined for both LOS and NLOS cases. Cell shapes are defined by the surrounding buildings, and energy reaches NLOS streets as a result of propagation around corners, through buildings, and between them.

3.3 *Base Coverage Urban*

3.3.1 C2 – Urban macro-cell

In typical urban macro-cell mobile station is located outdoors at street level and fixed base station clearly above surrounding building heights. As for propagation conditions, non- or obstructed line-of-sight is a common case, since street level is often reached by a single diffraction over the rooftop. The building blocks can form either a regular Manhattan type of grid, or have more irregular locations. Typical building heights in urban environments are over four floors. Buildings height and density in typical urban macro-cell are mostly homogenous.

3.4 *High-speed*

3.4.1 D2 – Moving networks

Propagation scenario D2 (“Rural Moving Network”) represents radio propagation in environments where both the AP and the UE are moving, possibly at very high speed, in a rural area. A typical example of this scenario occurs in carriages of high-speed trains where wireless coverage is provided by so-called moving relay stations (MRSs) which can be mounted, for example, to the ceiling. Note that the link between the fixed network and the moving network (train) is typically a LOS wireless link whose propagation characteristics are represented by propagation scenario D1.

4 Path Loss Models

Path-loss models at 5 GHz for considered scenarios have been developed based on measurement results and results from literature. The fixed parameter path-loss models have usually the form as in (4), where *d* is the distance between transmitter and receiver in [m], f_c is the system frequency in [GHz], the fitting parameter *A* includes the path-loss exponent parameter and parameter *B* is the intercept, third term of the sum gives the dependency on frequency and the last term *X* is an optional environment specific element (like e.g. wall attenuation in A1 NLOS)

$$PL \quad A\log_{10}(d\ \mathrm{m}) \quad B \quad 20\log_{10}\frac{f_c\ \mathrm{GHz}}{5.0} \quad X \tag{4}$$

The models were generalized for the frequency range 2 – 6 GHz and different antenna heights. The path-loss models have been summarized in the Table 4-1, either the variables of (4) are defined or a full path loss formula is given.

Free space attenuation referred in the table is

$$PL_{\mathrm{free}} \quad 46.4+20\log_{10}(d\ \mathrm{m})+20\log_{10}(f\ \mathrm{GHz}/5.0) \tag{5}$$

The shadow fading is log-Normal distributed and standard deviation of the distribution is given in decibels.

Table 4-1

Summary table of the path-loss models

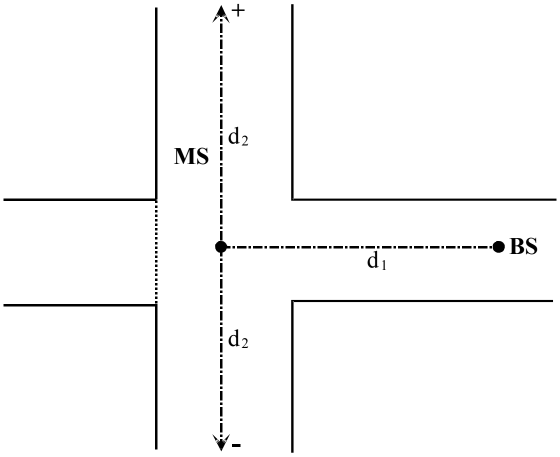
Scenario		Path loss [dB]	Shadow fading std [dB]	Applicability range, antenna height default values, notes
A1	LOS	$A = 18.7$, $B = 46.8$	σ = 3	3m < d < 100m, $h_{BS} = h_{MS} = 1... 2.5$m
	NLOS1)	$A = 36.8$, $B = 43.8$	σ = 4	same as A1 LOS
	NLOS2) heavy walls:	$A = 20$, $B = 46.4$, $X = 5n_w$	σ = 6	same as A1 LOS, n_w is the number of walls between BS and MS
	light walls:	$A = 20$, $B = 46.4$, $X = 12n_w$	σ = 8	
B1	LOS	$PL \quad \max\ 22.7\log_{10}(d_1) \quad 41.0$ $20\log_{10}\ f_c/5.0\ \ , PL_{free}$	σ = 3	30m < d_1 < d'_{BP} 4)
		$PL \quad 40.0\log_{10}(d_1) \quad 9.45 \quad 17.3\log$ $17.3\log_{10}(h'_{MS}) \quad 2.7\log_{10}\ f_c$	σ = 3	d'_{BP} < d_1 < 5km h_{BS} = 10m, h_{MS}= 1.5m
	NLOS	$PL \quad PL_{LOS}(d_1) \quad 20 \quad 12.5n_j \quad 10n_j\ \mathrm{l}$ where $n_j \quad \max 2.8 \quad 0.0024d_1\ , 1.84$ and PL_{LOS} is the path loss of B1 LOS scenario.	σ = 4	10m < d_1 < 5km, w/2 < d_2< 2km 5) w =20m (street width) h_{BS} =10m, h_{MS}=1.5m
B4	NLOS	$PL \quad PL_b \quad PL_{tw} \quad PL_{in}$, 3) $PL_b \quad PL_{B1}(d_{out} \quad d_{in})$ $PL_{tw} \quad 14 \quad 15(1 \quad \cos(\theta))^2$ $PL_{in} \quad 0.5d_{in}$	σ = 7	3m<d_{out}+d_{in}< 1000m, h_{BS}=10m, h_{MS}=3n_{Fl} +1.5m
C2	NLOS	$PL \quad 44.9 \quad 6.55\log_{10}(h_{BS})\ \log_{10}(d)$ $5.83\log_{10}(h_{BS}) \quad 20\log_{10}\ f_c/5$	σ = 8	50m < d < 5km, h_{BS} = 25m, h_{MS} = 1.5m
D2	LOS	A =21.5, B = 44.2	σ = 4	30m < d < d_{BP}, 6)
		$PL \quad 40.0\log_{10}(d) \quad 10.5 \quad 18.5\log_{10}$ $18.5\log_{10}(h_{MS}) \quad 1.5\log_{10}\ f_c/$	σ = 6	d_{BP} < d < 10km, h_{BS} = 32m, h_{MS} = 1.5m

1) A1 NLOS Room-to-Corridor scenario

2) A1 NLOS Room-to-Room through wall scenario
3) PL_{B1} is B1 path-loss, d_{out} is the distance between the outside terminal and closest point of the wall to the inside terminal, d_{in} is the distance from wall to the inside terminal, θ is the angle between the outdoor path and the normal of the wall, n_{Fl} is the number of the floor. (Ground floor is the number 1.)
4) $d'_{BP} = 4\ h'_{BS}\ h'_{MS}\ f_c/c$, where f_c = center frequency and c = velocity of light and h'_{BS} and h'_{MS} are the effective antenna heights at BS and MS respectively: $h'_{BS} = h_{BS} - 1.0$m, $h'_{MS} = h_{MS} - 1.0$m, where 1.0m is the effective environment height in the urban environment.
5) d_1 and d_2 have been explained below in Figure 3.
6) $d_{BP} = 4\ h_{BS}\ h_{MS}\ f_c/c$,, where h_{BS} and h_{MS} are the actual antenna heights.

Figure 3

Geometry for d_1 - d_2 path-loss model



5 Channel Model Parameters

Channel model parameters are given in the following sub-sections. The parameters are extracted from extensive radio channel measurements conducted in IST-WINNER project and from existing literature.

5.1 Geometry Based Stochastic Models

The complete parameterization for the primary model scenarios is given in Table 5-2.

Table 5-2 Channel model parameters

Scenarios		A1		B1		B4	C2	D2a
		LOS	NLOS	LOS	NLOS	NLOS	NLOS	LOS
Delay spread σ_{DS} $\log_{10}$([s])	μ	-7.42	-7.60	-7.44	-7.12	-7.31	-6.63	-7.4
	σ	0.27	0.19	0.25	0.12	0.36	0.32	0.2
AoD spread $\sigma_{ASD}$$^{++}$ $\log_{10}$([ ])	μ	1.64	1.73	0.40	1.19	1.08	0.93	1.07
	σ	0.31	0.23	0.37	0.21	0.42	0.22	0.31
AoA spread σ_{ASA} $\log_{10}$([ ])	μ	1.65	1.67	1.40	1.55	1.76	1.72	1.5
	σ	0.26	0.14	0.20	0.20	0.14	0.14	0.1
Shadow fading σ_{SF} [dB]	σ	3	6	3	4	7	8	2.5
Cross-Correlations **	σ_{ASD} vs σ_{DS}	0.5	-0.1	0.5	0.2	0.3	0.4	0.1
	σ_{ASA} vs σ_{DS}	0.7	0.3	0.8	0.4	0	0.6	0.2
	σ_{ASA} vs σ_{SF}	-0.4	-0.4	-0.5	-0.4	0	-0.3	-0.1
	σ_{ASD} vs σ_{SF}	-0.1	0	-0.5	0	-0.3	-0.6	-0.1
	σ_{DS} vs σ_{SF}	-0.7	-0.5	-0.4	-0.7	0.5	-0.4	-0.7
	σ_{ASD} vs σ_{ASA}	0.4	-0.3	0.4	0.1	-0.1	0.4	-0.5
Delay distribution		Exp	Exp	Exp	Uniform 800ns	Exp	Exp	Exp
Delay scaling parameter r_τ		3	2.4	3.2	—	1.8	2.3	3.8
XPR$_V$ [dB]	μ	11.4	9.7	8.6	8.0	4.0	7.6	6.9
	σ	3.4	3.5	1.8	1.8	11.2	3.4	2.3
XPR$_H$ [dB]	μ	10.4	10.0	9.5	6.9	9.5	2.3	7.2
	σ	3.4	3.1	2.3	2.8	11.3	0.2	2.8
AoD and AoA distribution		Wrapped Gaussian						
Number of clusters		12	16	8	16	12	20	4
Number of rays per cluster		20	20	20	20	20	20	20
Cluster ASD		5	5	3	10	5	2	2
Cluster ASA		5	5	18	22	8	15	3
Per cluster shadowing std ζ [dB]		6	3	3	3	4	3	3
K-factor [dB]		8.3 –0.06d	—	3+0.0142d	—	8.1	—	6
Correlation distance [m]	σ_{DS}	7	4	9	8	10	40	64
	σ_{ASD}	6	5	13	10	11	50	25
	σ_{ASA}	2	3	12	9	6	50	40
	σ_{SF}	6	4	14	12	4	50	40

[+] Scenarios C1 LOS and D1 LOS contain two shadowing std. deviations; one (left) for before and one (right) for after the path loss breakpoint.

[++] Angle of departure spread σ_{ASD} corresponds to σ_Φ and angle of arrival spread σ_{ASA} to σ_φ in the text.

* For scenario B3, XPR$_H$ is not available. In the channel model implementation, these values have bee substituted by the XPR$_V$.

** The sign of the shadow fading is defined so that positive SF means more received power at MS than predicted by the path loss model.

Table 5-3 Expectation (median) output values for large scale parameters.

Scenario		DS (ns)	AS at BS (º)	AS at MS (º)	ES at BS (º)	ES at MS (º)
A1	LOS	40	44	45	8	9
	NLOS	25	53	49	11	13
B1	LOS	36	3	25		
	NLOS	76	15	35		
B4	NLOS	49	12	58	10	10
C2	NLOS	234	8	53		
D2	LOS	39	5	30		

Table 5-4 **Expectation (median) output values of large scale parameters for bad urban scenarios (FS = far scatterer).**

Urban Scenario	DS (μs)	AS at BS (º)	AS at MS (º)	Power of the 1st FS cluster (dB)	Power of the 2nd FS cluster (dB)	Delay of the 1st FS cluster (μs)	Delay of the 2nd FS cluster (μs)
Micro	0.48	33	51	-5.7	-7.7	1.1	1.6
Macro	0.63	17	55	-9.7	-13.0	3.1	4.8

5.2 Reduced Variability Models

In the CDL model each cluster is composed of 20 rays with fixed offset angles and identical power. In the case of cluster where a ray of dominant power exists, the cluster has 20+1 rays. This dominant ray has a zero angle offset. The departure and arrival rays are coupled randomly. The CDL tables of all scenarios of interest are given in 7, where the cluster power and the power of each ray are tabulated. The CDL models offer well-defined radio channels with fixed parameters to obtain comparable simulation results with relatively simple channel models for calibration purpose.

6 Proposal

It is proposed that IEEE 802.16 task group m discusses this contribution and that Sections 2, 3, 4 and 5 are included – entirely or partially – in the family of 802.16m channel models as appropriate.

7 References

[1] PROPOSED MIMO CHANNEL MODEL APPROACH FOR EVALUATION OF AIR INTERFACE PROPOSALS FOR

IMT-ADVANCED, Document 8F/1148-E, Question ITU-R 229/8, ITU-R WP8F Meeting in Cameroon, January 2007.

[2] PROPOSED MIMO CHANNEL MODEL PARAMETERS FOR EVALUATION OF AIR INTERFACE PROPOSALS FOR IMT-ADVANCED, Document 8F/1149-E, Question ITU-R 229/8, ITU-R WP8F Meeting in Cameroon, January 2007.

[3] P. Kyösti (Ed.), "IST-WINNER II D1.1.1, WINNER II interim channel models", V1.2, Feb. 2007. (https://www.ist-winner.org/deliverables.html)