Project	***IEEE 802.16m Group***
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Re:	*Response to the call for technical proposal regarding IEEE Project 802.16m*
Abstract	*We present a suggested text for a submission by IEEE 802.16m to the ITU-R group 8F on channel modeling.*
Purpose	*To provide general information on channel modeling to IEEE 802.16m.*
Notice	
Release	
Patent Policy and Procedures	

Motivation for IEEE 802.16m channel model submission to ITU

1. Introduction

The ITU is currently in the process of establishing performance evaluation criteria for IMT-Advanced that specify minimum capabilities and process and items for the test evaluation. As part of the process, channel models have to be defined. Due to the enhanced capabilities, increased bandwidth, and increased variety of envisioned deployment scenarios, existing channel models cannot be used. Such existing models include the COST207 channel models [1], which have been used for establishing the GSM standard; the ITU-R channel models, which influenced the development of third-generation cellphones [2]; the HIPERLAN channel models, which were used for 802.11 systems [3], and the COST 231 pathloss models, which have been applied for a number of microcellular systems [4], and the SUI (Stanford University Interim) models that have been used extensively in the development of the 802.16 standard [5].

In a presentation to the ITU [26], three companies propose a channel model methodology and suggest it for the inclusion into the ITU evaluation criteria. However, as we will outline below, the document has two major drawbacks from a IEEE 802.16m perspective:
(i) it does not adequately reflect scenarios with stationary users – a situation that is the main strength of the current 802.16 standard, and backwards compatibility to which will constitute an important argument in the development of 802.16m.
(ii) it contains a number of somewhat debatable statements. Having those statements in the official evaluation methodology will make the creation of simulation programs and results more difficult for 802.16m participants.

For these reasons, we suggest that the IEEE 802.16m group should make a submission of its own to the ITU-R at their next meeting in May. To further this process, the current document outlines a text proposal that we suggest 802.16m could submit to the ITU.

The remainder of the document is organized the following way:. in section 2, we discuss Ref. [26] and point out the possibilities of improvement from 802.16m's point of view. A text that proposes an alternative model can be found in a separate document, C 802.16m-??. Section 3 finally discusses the establishment of operating environments and parameters, and suggests goals for a further submission on this topic by 802.16m.

2. Discussion of Ref. [26]

The document [26] gives a generic framework for modeling of MIMO channels. In a sense, it has similarity with our parallel document C 802.16m-??, in that it tries to first establish the pros and cons of different channel modeling approaches. However, it contains a number of points that might be improved, including nomenclature that does not agree with the established literature (and thus might lead to confusion of the readers), statements about the generality of different approaches which we tend to disagree with, and some debatable statements on the spatial scales over which some parameters vary.

2.1. Discussion of Sec. 2

We first comment on the nomenclature of [26]. The document categorizes channel models into "stochastic", "deterministic", and "geometry-based stochastic".

In the nomenclature of [26], a "stochastic" model is a model that describes the statistics of the impulse responses or transfer functions at antenna elements, and that furthermore assumes that the fading is independent at the different antenna elements, like the model that was used in the theoretical work of [13]. For the more general case of an (almost) arbitrary correlation of the signals at the antenna elements, [26] uses "correlation-matrix-based". We feel that *any* model that describes stochastic properties of the impulse response is a stochastic model, and that the special restriction of independent fading at the antenna elements does in no way make a model more or less "stochastic". We suggest that the name "analytical" models should be used for any category of models that describes the signals measured at the antenna terminals; this nomenclature is already in widespread use in the academic literature as well as in European cooperation projects like NEWCOM (see, e.g., [10]).

Models that describe the directions-of-arrival and directions-of-departure are called "geometry-based" stochastic models. This is a description that seems to deviate from the usage as established in the literature, and also does not seem to be very intuitive. Geometry is involved only in the sense that angles of multipath components are given. We suggest that, following the established literature (dating back to the original work [12]), such models be called "double-directional", or, possibly, "physical" models as in [10]. The term "geometry-based stochastic model has been used since the 1990s for models that prescribe random locations of scatterers (interacting objects), and derive double-directional impulse responses from those locations via simple ray-tracing procedures (see, e.g, [22], [23] [27], [28]).

2.2. Discussion of Sec. 3

Ref. [26] states that the IEEE 802.11n models fall into the category of correlation-matrix-based MIMO models. In our opinion the model is essentially a double-directional model, though correlation matrix implementations (where the matrices are computed from the double-directional model) are also given in the channel model document.

[26] also state that it is an inherent feature of correlation-matrix-based models that the correlation matrices at the two ends of the link are combined via the Kronecker product to give the total correlation matrix. However, we think that the Kronecker structure is not an inherent property of correlation-matrix based models. While the Kronecker model has gained some popularity, it is only a subclass of a more general correlation matrices. Other models that do not use the Kronecker model include the full-correlation-matrix model [29, Chapter 7.4], and the Weichselberger model [14]. Similarly, it is not an inherent feature of correlation-matrix based models that the channel impulse response as a function of angle and delay is separable; by introducing delay-dependent correlation matrices, correlation-based model can be made more general.
Also, there seems to be no fundamental reasons why smooth transitions from LOS to NLOS in the pathloss model should not be possible.

We agree that the correlation-based models are antenna dependent, that inclusion of the correlation between shadowing and delay spread is difficult, and that time evolution of large-scale parameters is difficult. For this reason, we also support to use a non-correlation-matrix based modeling approach.

2.3. Discussion of Sec. 4,5

The literature list of [26] might be made more complete by several of the papers cited in the current document. In particular, the COST 259 channel model, the first standardized, MIMO-capable channel model, already introduced (in 2001 !) temporal evolution of parameters [30], and thus seems relevant

Several of the statements in the table in Sec. 5 are not completely clear. It is not obvious why stochastic correlation-based models cannot be made at least partly scalable. Also, the expression "statistical coverage" does not have a clear definition.

2.4. Discussion of Sec. 6

The above-mentioned comments on the nomenclature apply to Sec. 6, too. The nomenclature for "rays" and "clusters" disagrees with the 3GPP-SCM model [24].

Equation (1) does not describe the transfer matrix, but the channel impulse response matrix. Eq. (3) does not describe the "channel", but rather the channel impulse response.

The explanation of the terms in Eq. (3) shows some misprints: λ is the wavelength, not the wave number. In the second line, the second $\alpha_{n,m,VV}$ should instead read $\alpha_{n,m,VH}$. A similar typo occurs in Eq. (3): the lower right element in the matrix should be $\alpha_{n,m,HH}$.

It is stated, furthermore, that the variations of the delays, powers, and directions of arrival occur on a smaller spatial scale than the variations of the shadowing and delay spreads. This statement does not seem to be supported by measurements, and indeed seems counter-intuitive: the variations of the powers of the separate paths, for example, are created by shadowing, so that in our interpretation the variations of path powers and variations of shadowing occur on the same spatial scale (and are, indeed, one and the same).

The document does not define a Doppler spectrum explicitly, saying that it is determined by power and angular information combined with array characteristics. Studies of other documents indicate that the model only describes Doppler variations due to a moving terminal. While this may be justified for some cases (see also the extensive discussion in [7]), it is a considerable restriction of generality that is made to achieve a simplification of the model. In the experience of the IEEE 802.16 group, temporal variations due to moving scatterers are of critical importance.

2.5 Summary

Due to the above-mentioned discussion items, we suggest that 802.16m should suggest our parallel document C 802.16m-?? as a generic channel modeling document to ITU-R 8F, as a preferable alternative to the submission [26].

3. How to obtain the model parameters

In the companion document, we have only discussed the generic modeling principle, but not the measurement environments, and the actual values for the parameterization of the model in the different environments.

To a large degree, the model can rely on the parameterization done in the COST 259, COST 273, 3GPP and WINNER 1 and WINNER 2 projects. In the following, we point out the relationship between those models and the approach suggested in this work. We also point out the weak points in the parameterization of the models, and suggest future work (to be done until the May meeting).

The approach suggested in this paper shows large similarities with the approach of COST 259, COST 273, and 3GPP. The continuous model suggested here is a superset of the COST 259 macrocell model; extensions presented here include the diffuse scattering and the temporal variations due to moving scatterers. The discretization of the continuous model is adopted from 3GPP; note that the continuous 3GPP model can be interpreted as a subset of COST 259.

The approach in this document shows some resemblance to the Winner model, if we restrict our model to the case of a single cluster. Note that Winner speaks of "clusters" when they mean zero-delay clusters, i.e., multipath components with effectively the same delay, and only slightly varying angles. This is different from the cluster in this document: Clusters in the Winner model do not have a delay spread, have a *fixed* angular spread; clusters in our notation have a lognormally varying delay spread and angular spread, and the variations of the two are correlated (similar to the *total* spread in Winner). The discretization of the DDPS *within* a cluster follows the recipe of 3GPP. We also note that COST 259 has established that for "typical" macrocellular environments (e.g., typical urban), the number of clusters is close to 1 (this is also similar to the 3GPP parameters); thus there is a strong similarity to the Winner models. However, for micro- and picocellular scenarios, both COST 259 and COST 273 identified a larger number of clusters. Thus, there is no strict correspondence between the Winner parameters and the COST 259/COST 273 parameters anymore.

Future work for the 16m group could concern the following issues. We note here that Winner has the most extensive measurement campaigns, and also is one of the proponents of ITU models. In order to reach a complete and generally accepted model, it thus seems useful to adapt as many of their results as possible. However, we also think that the Winner model is not complete.

- Establish a list of environments that 16m considers as essential. The classification of COST 273, as well as of Winner, can serve as a basis
- Adapt the parameters from COST 259, COST 273, 3GPP, and Winner, to our generic model. In particular in the case of the Winner models, this will require some modifications, as Winner looks at a single cluster, while we are considering multiple clusters.
- Fill the gaps in the list of parameters with results from the literature. For example, elevation spread data are available only for a few environments in COST 273 and Winner. In the cases that COST, 3GPP and Winner have contradictory parameters, decision have to be made based on the established literature. For example, the over-the-rooftop propagation model contradicts the IEEE 802.16j model. Also, the outdoor-to-indoor pathloss can be improved: the Winner model is missing a correction factor for MS height (on which floor); missing a distinction of whether BS has LOS to the window or not.
- Extend the Rice-factor model of Winner. Winner assumes a deterministic Rice factor; however, results from COST show that it is actually a random variable. We might adopt the Winner Rice factor as mean, and prescribe a lognormal random variation around this mean (variance should be determined from the literature).
- A critical point is the number of (discretized) paths. Winner adopts a model where each path (cluster in their notation) has 20 discrete subpaths. As a consequence, typically 100 or more subpaths have almost the same strength (are within a dynamic range of <10dB). This contradicts many measurements that found at most 20 MPCs within a dynamic range of 10 dB; and it has important implications for system design: it "pretends" a multipath richness (and thus ability to support high capacity) that is not present in

the actual channels. We thus propose to work on a refined discretization procedure that shows a more realistic number of subpaths.

4. Summary and conclusions

We have outlined why current channel model submissions to ITU-R do not fulfill the requirements of 802.16m. Based on our additional document 802.16m-??, we suggested further work to parameterize the generic channel model.

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