DIRECTIONAL CHANNEL MODELLING IN COST259 SWG 2.1

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Abstract

This paper summarizes the achievements of Subworkinggroup 2.1 (SWG2.1) of the COST259 initiative. A common approach for modelling the time-variant wideband angular-dispersive radio channel for link-level simulations is derived and the main parameters are described. The basic modelling philosophy is a stochastic signal description where deterministic a-priori information about the environment enters the model. The model is a generalization of the well-known COST207 models in three respects: (i) the directions of arrival both at the base station and the mobile station are included, (ii) not only macrocells, but also micro- and picocells are envisaged, (iii) large scale variations are modelled. To allow efficient simulations while still including large-scale variations, we have to distinguish between *external*, *global*, and *local* parameters. As part of the external parameters, a set of *radio environments* has been defined each of which is capable of generating several *propagation scenarios*. Global parameters tune the statistics of the local parameters and the actual realization. The relation between directional and non-directional models is touched by means of the wide-sense stationary uncorrelated-scattering (WSSUS) concept.

INTRODUCTION

In February 1998 COST259 has founded the subgroup on directional channel modelling (SWG2.1) as part of Working Group 2 ("Propagation and Antennas"). The aim of this subgroup is to propose a common method for modelling the mobile radio channel for direction-resolving systems. This is especially important for performance assessment and comparison of adaptive antenna systems.

COST Action 207 [4] has developed wideband propagation models that have gained widespread usage not only through their adoption in the GSM standard but also because of their simplicity. However, increasing demand on capacity has led to the deployment of micro- and picocells and directional antennas. Since the COST207 models have not aimed to include that, a more general modelling concept is required today. Although some efforts [10] have been made to extend the ITU-REVAL channel profiles [6] with directional information needed for adaptive antenna systems, no consistent and flexible model is available today. An interesting attempt is made in the CODIT Final Propagation Model [1]. This model is based on a fixed number of scatterers. For each cell type parameters of the statistical distributions of the random parameters controlling the CIR are given. However, the assumptions made for the model appear to be too rough. As is most important however, it does not model directions of arrival (DOAs) at the base station.

The COST259 model is trying to provide a more general and flexible framework that also covers large-scale variations of the channel, while still allowing for small-scale models with similiar simplicity to the earlier-mentioned approaches. The parameter selection relies on previous models as well as recent measurement results. It uses the findings of Hata-Okumura and Walfisch-Ikegami as well as COST231 for modelling the pathloss in different environments; COST207 for global power delay profiles in macrocells; TSUNAMI-II in respect to the ADPS shape of clusters in macrocells [2], and the CODIT scenario selection in micro- and picocells. The approach of distinction between global/local and location-dependent instead of time-dependent channel functions stems from the Magic WAND project [5], the clustering approach from the METAMORP project [9].

GENERAL MODELING PHILOSOPHY

The necessity to cover all relevant propagation effects calls for a parametric modeling approach. By a stochastic set of parameters that are input to a deterministic relationship based on physical considerations, all cases of radio propagation can be covered while the number of parameters are kept small. The physical properties of a radio link are described by a propagation channel model. Radio propagation is location-dependent, i. e. a *propagation scenario* is determined by the location of the base station (BS), the mobile station (MS), and the objects interacting with the electromagnetic field. The *radio environment* is defined as a type or class of propagation senarios hat exhibit a typical behavior that can be related to the topographical surroundings in which the BS and MS reside. For example, in the macrocellular radio environment, it can be regarded as “typical” that there is local scattering around the MS, while the BS is mounted higher than the surrounding scatterers. Consequently, the multipath signals arrive at the MS from all directions, while the signals at the BS are restricted to smaller angular regions. In the model, the propagation conditions in a radio environment are characterized by the *global parameters* and global probability density functions (pdfs). The latter determine the statistics of the entirety of propagation scenarios related to the radio environment. Propagation scenarios are determined by *local parameters*, which are in general random. It can be expected that for movements of the MS in a small area the latter do not change. Thus, the local parameters control the small-scale behavior of the channel impulse response.

An important aspect included in the COST259 model is the *clustering nature* of the propagation channel in macrocells. While in microcells scattering objects are often smeared uniformly over the whole delay- and azimuth-range, in macrocells there are clusters in the ADPS that are separated by both, azimuth and delay. While the shape of the ADPS for each such cluster is approximately the same, its position, power and spread are different. Therefore, the ADPS *shape* is a deterministic global parameter while the positions of the clusters are local parameters (clusters appear/disappear on a large-scale basis). Cluster positions remain fixed on a small-scale basis, i.e. for the lower-level simulation. The multipath components (MPCs) within each cluster are also local parameters, their position in delay/azimuth and their power and Doppler shift each following certain (global) pdfs. The instantaneous fading situation is then a result of finite bandwidth and antenna-aperture of the system under consideration.

MODEL APPLICATION

Chart 1 shows how to apply the COST259 directional channel model in practice. The user prescribes external parameters (e.g. carrier frequency, BS position) that remain valid throughout the whole simulation. The radio environment to begin with is also chosen by the user. For each radio environment, a set of of global parameters is specified. These global parameters could for instance be stored in a lookup-table. Given the global parameters, the local parameters for the propagation scenario can be generated from their pdfs. With this information, the small-scale simulation for this scenario can be invoked.

It is well-known that the WSSUS assumption is very useful for the design of stochastic radio channel simulators [3]. Our concept allows the small-scale characteristics (i.e. within a local stationarity region) that are described by WSSUS models to be reproduced by any small-scale fading simulators.

As soon as the MS approaches the borders of a local stationarity region due to shadowing, a new propagation scenario is generated on the upper level. This could occur e.g. if the distance between the MS position and its starting position in the same stationarity region exceeds the correlation length of the shadow fading (5 to 12m in urban environments). Corresponding to the bigger time-scale on which these large-scale effects occur, quickness is not an issue for the upper level and so more sophisticated models can be implemented here.

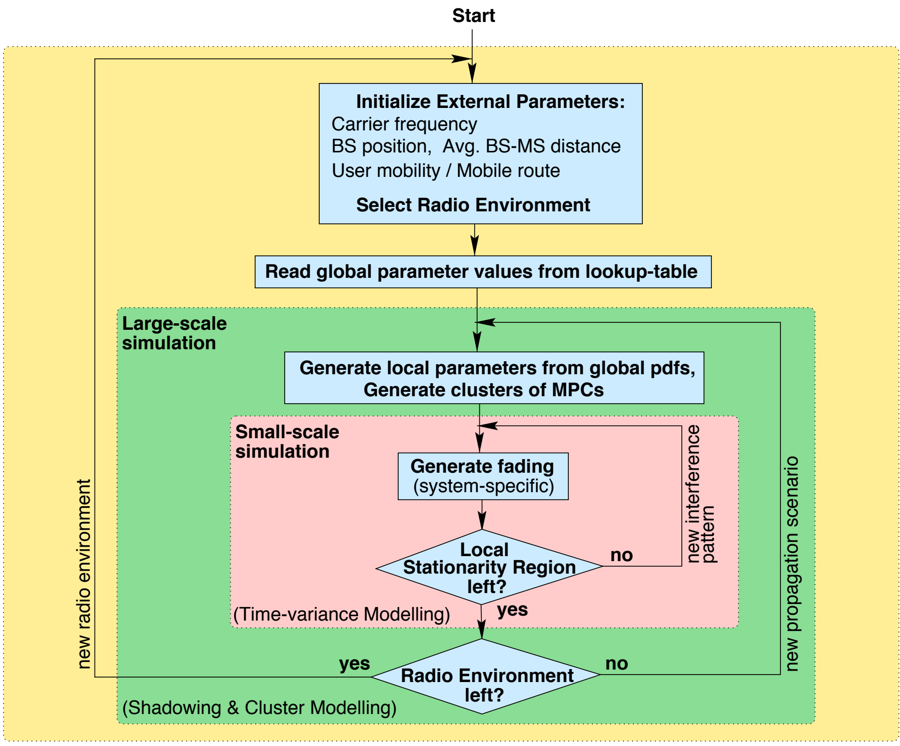

Figure 1: Application of the COST259 SWG2.1 directional channel model.

RADIO ENVIRONMENTS

To cover all relevant communication situations, the following radio environments have been defined: for macrocells, generalizations of the COST207 radio environments have been chosen: MACRO-GTU, MACRO-GBU, MACRO-GRA, MACRO-GHT, referring to generalized typical urban, bad urban, rural area, and hilly terrain, respectively. This was done to retain the COST207 models as special cases of the COST259 models, so that comparisons with earlier simulation work can be done.

For micro- and picocells it is more difficult to replace the physical channel by a set of (virtual) clusters that generate the delay-angular dispersion. The reason is that large-scale and small-scale effects lie very close together or are overlapping. Therefore movement of clusters would have to be implemented on a small-scale basis which is computationally expensive. Also, transitions between physically very different situations (e.g. line-of-sight/no line-of-sight) occur very often. Due to this stronger deterministic dependency of the channel on the geometry of wave propagation in micro- and picocells, we rely on scenarios (street canyon, crossing, open place/square for microcells; corridor, factory hall, office room, large hall/lounge for picocells) as elementary units to more accurately reflect the actual situation and let the mobile movement induce the transitions between them.

PARAMETER EVALUATIONS

In order for each effect to be reproduced, a large amount of parameters has to be specified. To give but one example, we have chosen a parameter that is very characteristic for our modelling philosophy. The "number of clusters" is a global parameter and therefore has to be specified by a pdf. Fig. 2 shows evaluations of the number of clusters for a downtown urban (Munich), an urban (Dresden) and a suburban (Ilmenau) environment. It seems that the number of clusters can be modelled by a Nakagami distribution. As can be seen, the median is approximately one for Munich, two for Dresden and three for Ilmenau. This means that more than one cluster exists with high probability which is in confirmation to our modelling approach.

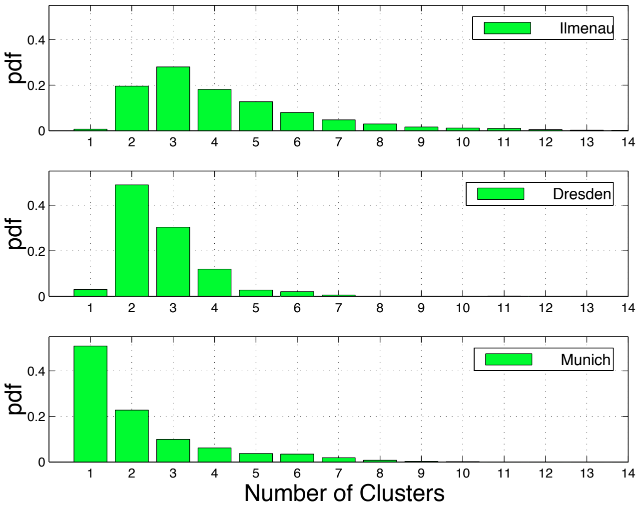

Figure 2: Occurrence of scattering clusters in different environments. Taken from [7].

CONCLUSION

We have presented the directional modelling approach chosen within COST259 by SWG2.1. The model is flexible, yet simple enough to allow easy inclusion in any system simulation. To make usage even more easy, MATLAB routines are being made available on the Internet under `http://www.nt.tuwien.ac.at/mobile/research/COST259/`. Also, more extensive descriptions and parameter definitions can be found there. Note however, that these parameters still underly modifications.

References

[1] *Final Propagation Model*. CODIT Public Report Number R2020/TDE/PS/DS/P/040/b1. CEC, June 1994.

[2] TSUNAMI-II Final Report. Technical Report, ACTS 020, 1998.

[3] M. Pätzold. *Mobilfunkkanäle*. Vieweg, Braunschweig/Wiesbaden, 1999.

[4] *Digital Land Mobile Radio Communications – COST207 Final Report*. Commission of the European Communities, 1989.

[5] B. H. Fleury, U. P. Bernhard, and R. Heddergott. Advanced Radio Channel Model for Magic WAND. *Conf. Proc. ACTS Mobile Telecommunications Summit'96*, pages 600–607, 1996.

[6] Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000. Technical Report Rec. ITU-R M.1225, ITU, 1998.

[7] Nadja Lohse. Parameter Validation for a Space-time Channel Model. In *COST259*, number COST259TD(99)109, 1999.

[8] M. Steinbauer, H. Asplund, I. de Coster, D. Hampicke, R. Heddergott, N. Lohse, A. F. Molisch. Mission Report – Modelling Unification Workshop. Number TD(99)061 in COST259, April 1999.

[9] Description of the Modeling Method. METAMORP Public Report C-2/1, 1999.

[10] P. Pajusco. Experimental Characterization of DOA at the Base Station in Rural and Urban Area. *Proc. IEEE VTC'98*, 1:993–997, 1998.