

Overview of COST 273 Part I: propagation modeling and channel characterization

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Abstract – This paper is an overview of COST 273 activities with special emphasis on electromagnetic propagation modeling. A summary is given of the entire project and some of its major achievements are outlined.

Keywords – Propagation modeling, channel characterization, MIMO systems, scenarios.

I. INTRODUCTION

Action 273 is a European project (start May 2001, end May 2005) within the COST (European COoperation in the field of Scientific and Technical Research, [1]) framework dealing with radio aspects of mobile and wireless networks. This paper is a presentation of Action's final report, [2], which has appeared also as a book, [3]. The first part of the paper describes briefly the structure of the Action, its work groups (WG) and sub-work groups (SWG) and their activities. The Section III overviews the work related to deterministic propagation methods and channel modeling and characterization. Special attention is paid to two major achievements (to the author's opinion) in Action 273: MIMO channel model and reference scenarios for radio network simulation and evaluation. Finally, some trends for the future, as foreseen by the Action participants, are given.

II. COST ACTION 273

The COST framework contains several areas, among them "Telecommunications and Information Society Technologies" (TIST) and Action 273 was part of this area. The Action 273 (Chairman: Prof. Luis M. Correia, Technical University of Lisbon, Lisbon, Portugal) emerged as follow-on from three previous COST projects, namely:

- COST 207: *Digital Land Mobile Radio Communications* (Mar. 1984 – Sep. 1988), which contributed to the development of GSM;
- COST 231: *Evolution of Land Mobile Radio (Including Personal) Communications* (Apr. 1989 – Apr. 1996), which contributed to the deployment of GSM1800 and to the development of DECT, HIPERLAN 1 and UMTS;
- COST 259: *Wireless Flexible Personalized Communications* (Dec. 1996 – Apr. 2000), which contributed to the deployment of DECT and HIPERLAN 1 and to the development of UMTS and HIPERLAN 2, as well as initial inputs to the next generations of HIPERLAN and 4th generation systems.

The main objective of COST 273 is "to increase the knowledge on the radio aspects of mobile broadband multimedia networks, by exploring and developing new methods, models, techniques, strategies and tools towards the implementation of 4th generation mobile communication systems", [4]. It considers frequencies ranging from the upper UHF up to millimetre waves, and data rates essentially higher than 2 Mb/s. It is also expected that it will contribute to the deployment of more or less standardized systems like UMTS and WLANs. The Action collaborates with other European projects in the TIST area, [4]. Results of the previous Actions have been taken by the industry and standardization bodies, e.g., ETSI – European Telecommunications Standards Institute; ITU-R – International Telecommunications Union – Radio Sector; 3GPP – Third Generation Partnership Project; the same is expected for the COST 273. The Action is structured in 3 Working Groups (WGs) and several Sub-Working Groups (SWGs):

- **WG 1** - Radio System Aspects. The WG1 members deal basically with: access techniques, modulation schemes, detection algorithms, signal processing, Multiple-Input Multiple-Out (MIMO) systems, and receiver structures. Joint sessions with Working Group 2 have considered MIMO channel modeling and the capacity of the MIMO channel and fading forecasting for adaptive systems. Achievements of WG 1 are reported mainly in Chapters 2 and 3 of [3]. (Note that, due to the need of joint treatment of numerous problems by experts from different WGs, the book [3] does not follow exactly the topics covered by the WGs as enumerated here.)
- **WG 2** - Propagation and Antennas. Topics addressed in WG2: propagation mechanisms, channel measurements, channel characterization, adaptive antennas, antennas modeling, and MIMO channels. Chapters 4 – 7 of the book are dedicated to the results obtained in WG 2.
 - SWG 2.1 - MIMO channel model. Goal: establishment of a model for the wireless channel that is suitable for MIMO systems, characterized by a set of parameters.
 - SWG 2.2 - Antenna performance of small mobile terminals. Goal: establishment of measuring techniques and of performance relations for antennas on small mobile terminals.
 - SWG 2.3 - Multidimensional channel measurements. Goal: Development of propagation channel measurement techniques and provision of measurement results to support channel modeling.
- **WG 3** - Radio Network Aspects. Topics encompassed in WG3: radio network planning, ad-hoc networks, traffic modeling, capacity and interference modeling, radio resources management, methodologies for performance

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evaluation of radio networks. The work done in WG 3 is summarized in Chapters 7, 8 and 9.

- SWG 3.1: Mobile radio networks reference scenarios.
Goal: definition of common reference scenarios to be used in the assessment of Radio Network Planning (RNP) and Radio Resource Management (RRM).

III. ACTIVITIES RELATED TO PROPAGATION MODELING AND CHANNEL CHARACTERIZATION

It is known that UMTS radio networks are very sensitive to variations of the radio environment and the traffic conditions, [5]. This requires UMTS planning to be based on reliable propagation models and detailed traffic predictions. Especially this is true when transition from one environment to another, with different propagation conditions, is due or when the automatic approach for UMTS planning is addressed. Nevertheless, the most accurate methods for wave propagation description available in electromagnetics are still not very often applied by the telecommunication engineers due to their complexity and large amounts of computer resources required. Generally, statistical models are preferred in the planning phase of a mobile radio system, where speed is more important than accuracy, while deterministic models are used in the design phase. Widespread adoption of otherwise physically meaningful, accurate and flexible deterministic propagation models is still very limited also by the cost and the reliability of the input databases (containing details on terrain, buildings etc.) they require. The work done essentially in WG 2 and SWG 3.1 of the Action has tried to reduce these two gaps: low use of accurate deterministic propagation methods and lack of accurate databases for them. The application of complicated methods aims to identify/solve as more problems as possible still in an early planning stage in order to facilitate the next steps.

Some of the well known deterministic methods have been applied to solve problems arising in antennas design and propagation modeling, among them:

- 1) integral methods (moment methods, physical optics and modal expansion);
- 2) differential equation methods (FDTD and Parabolic Equation (PE));
- 3) ray methods (tracing/launching and Gaussian beams).

A great number of Temporary Documents (TDs) reported during the Action have been dedicated to applicative aspects and comparative overviews of these methods including such issues as their database accuracy sensitivity, computation time, diffuse scattering modeling capabilities and performance metrics. Their specific applications, their pros and cons, may be read in Chapter 4 of [3].

The major part of the investigations/applications in the frame of Action 273 as for deterministic methods is dedicated to the ray methods. Ray tracing provides several advantages over traditional prediction methods: accurate site-specific field strength prediction, possibility to incorporate 3D antenna patterns and to obtain wide-band characteristics such as direction of arrival and multipath time delay. In this paper, to illustrate the ray methods applications, more details are given

on the results obtained in [5] which demonstrated the real need of more accurate propagation prediction. The authors of [5] quantified the advantage of accurate radio coverage predictions undertaking a case study for a UMTS radio network planning in a 5 km² area in Paris, France. The conclusion following from their results is that a conventional propagation model (as the well-known Hata-Okumura model or even its improved version COST231-Hata model) could

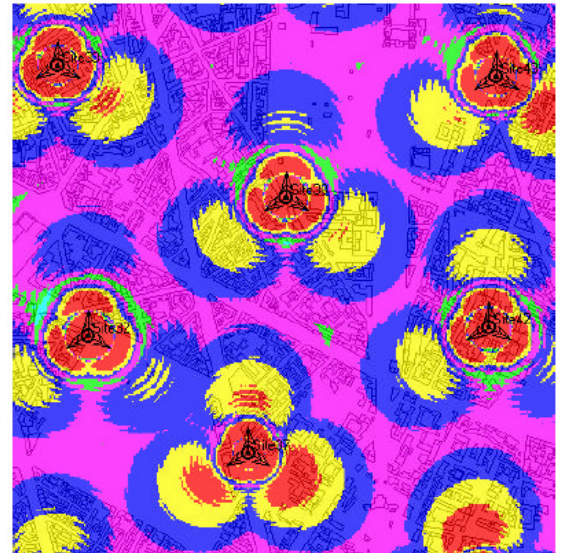


Fig. 1. Signal strength from empirical propagation predictions - COST231-Hata model. The building layout is not taken into account. (Fig. taken from [5])

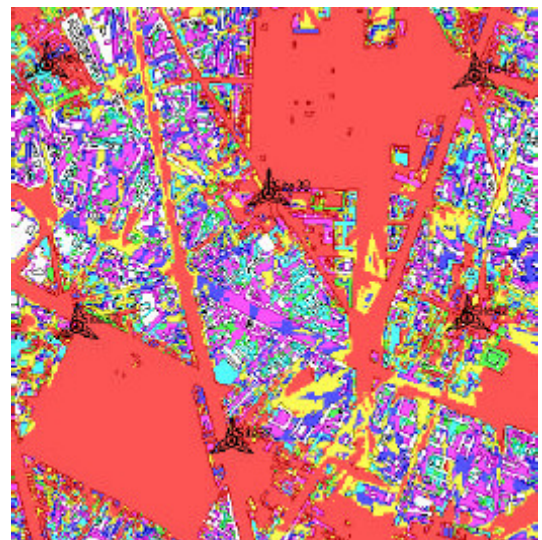


Fig. 2. Signal strength with ray tracing propagation predictions. Clearly seen are the canyon effect of streets and the impact of the buildings on the propagation. (Fig. taken from [5])

lead to erroneous planning with less than expected quality of service, unacceptable interference and building of more base stations than necessary, see Figs. 1 and 2. An accurate site-specific ray-tracing model, [6], integrated in the planning tool

allows the radio network planner to reach optimal numbers for the base station deployment and configuration while meeting the expected service level requirements. One of the exemplary quantitative results of the case study for urban environment in [5] is that the ratio of rejected calls determined by the ray-tracing model is 14 times higher compared to the ratio derived from predictions using a simple COST 231-Hata-model.

The ray tracing based prediction techniques have some weaknesses: they are unreliable under specific tropospheric conditions (ducting), suffer difficulties when transiting from one type of region/cell (say, rural) to other (urban). Some of these difficulties could be overcome using even more complicated differential equation based methods as the PE method. The advantage of the PE method is that, as a full-wave method, it accounts simultaneously and accurately for the wave diffraction, refraction and scattering propagation mechanisms. Its disadvantage in comparison to ray tracing is that the PE does not provide the information on angle of departure/arrival in a straightforward manner. The PE method application is described in details in [7].

As the channel characterization is concerned, the COST 273 participants dealt with “traditional” topics characterizing the variability of power received through the mobile radio channel such as:

- 1) path loss, its distance dependence and small- and large-scale fluctuations;
- 2) temporal and angular dispersion;
- 3) fading prediction techniques;
- 4) experimental channel characterization techniques;
- 5) statistical processing of measurements;

but in this area special attention was devoted to the MIMO channel model and the reference scenarios for radio network simulation and evaluation developed in Action 273. The specification of antenna arrays at both link ends by setting the number of antenna elements, their geometrical configuration and polarizations turns the propagation model into a MIMO

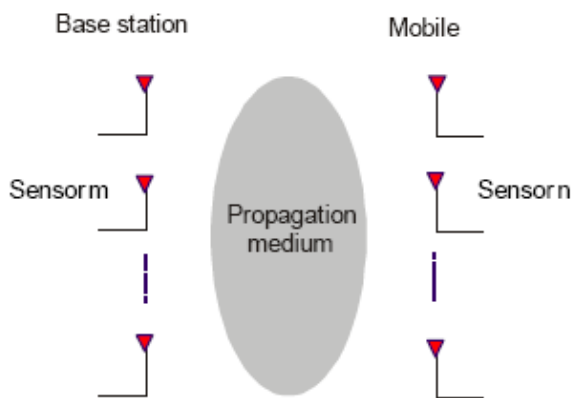


Fig. 3. Example of MIMO configuration (Fig. taken from [8])

channel model, see Fig 3. In order to make use of MIMO advantages, the space-time behaviour of the channel should be modeled. In general, from propagation point of view, a MIMO model has to meet the following requirements (as stated by COST 273):

- separation of the environment from the antenna arrays;
- adaptation to different environments;
- modeling of mobile movement;
- agreement with measurements;
- compliance with former models;
- precise, but by as few parameters as possible, analytical description of the spatial structure of the channel.

A very good example of fulfilment of these criteria may be found in [8], where the space-time behavior of the propagation channel is simulated on a ray-basis.

The reader may have noted the existence of discrepancy between the great efforts devoted to the development of new MIMO models during the last years and the almost lack of their validation. Still, a lot of work on models validation has been done within COST 273 and its novel MIMO model is mainly based on numerous and profound measurement campaigns reported and discussed during the Action. Its model is geometry based on the one hand and stochastic on the other, combining the best of both approaches, see Chapter 6 of [3] and report [9]. Nevertheless, it is to note that this novel concept is still to be validated as a whole.

In COST 273 special attention was paid also to the term *scenario* due to the great diversity in its use. In general, the term reflects a consistent set of parameters. At the propagation level (of which we are concerned in this paper), COST 273 presents a large variety of types of *scenarios*, reflecting the physical environment: one speaks of outdoor macro-, micro- and pico-cellular scenarios with or without line-of-sight, indoor office scenario, etc. In many cases the results of different researchers (both theoretical and experimental) appeared not to be comparable due to the different assumptions and approaches when describing the scenarios. This problem becomes evident especially when dealing with comparison of different RRM techniques and RNP strategies. Finally, a *Spatial Propagation Scenario* in COST 273 was introduced as a set of parameters, defining the spatial and multiuser situation, and the environment, with direct consequences on the propagation channel properties. A scenario like this is conceived to be used by several inter-working parties, in order to be able to compare performance, or to extract conclusions of how the propagation channel affects such performance (the classification of scenarios still needs to be motivated). To cope with scenario related problems, a new initiative raised within COST 273 SWG 3.1: the Mobile Radio Access Network Reference Scenarios (MORANS), which is oriented to provide a set of scenarios, parameters and models to be used as a common simulation platform. Due to the complexity of the Reference Scenarios reflecting the approaches used when evaluating RNP or RRM strategies, it is agreed that two types of scenario elements will be provided: synthetic scenarios, based on simple and regular geometrical lay-outs and simplified models, which make easy the interpretation of the results, and real-world based scenarios, where some data is taken from the real world, thus making their use more complex but providing the possibility to test radio network algorithms under more realistic conditions. In order to be practically relevant, the Reference Scenarios have to satisfy a number of requirements:

- ease of use;
- limited number of cases;
- defined interfaces between different parts of the scenario;
- extendibility.

Finally, it is clear that the success of further research requires a deeper integration of skills among the various disciplines involved in the design and development of mobile communication systems: for instance, the signal processing issues are closely related to propagation issues. In the future, investigations of the inter layers interactions will be needed. Some prospective topics are related to the advanced planning (Hybrid Networks - radio network architecture and automatic planning methods for GSM/UMTS). The creation and maintenance of reference scenarios will continue and their definition will involve the participation of physical layer, propagation, and networking experts. More investigations will be dedicated also to the Ultra Wide Band communications and MIMO communications.

More details on COST 273 may be found on <http://www.lx.it.pt/cost273>.

IV. CONCLUSION

This paper has summarized a small part of the huge number of topics the COST 273 participants dealt with. Demonstrated is the need of precise propagation modeling and channel characterization. These two topics have been chosen because of their importance: all the rest of signal processing, coding and deployment hinges on the accurate modeling.

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