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An Overview on COST 273 - Towards Mobile Broadband Multimedia Networks

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ABSTRACT

A brief overview is presented on an European project within the COST framework, COST 273, which deals with radio aspects of mobile and wireless networks. In particular, radio interface, propagation and antennas, and radio network aspects are addressed by the project, grouped into three Working Groups. Within the Working Groups, Sub-Working Groups deal with more specific issues, namely, MIMO systems, antennas for mobile terminals, measurements procedures, and scenarios for network planning and organisation. Detailed information can be found at http://www.lx.it.pt/cost273.

INTRODUCTION

There is no doubt today that mobile and wireless communications have an increasing importance in the telecommunications world, and that this trend will continue in the next few years. Moreover, Europe wants to continue to play a leading role in this area, as was the case with GSM (the well known 2nd generation system, which is a worldwide success). This is also expected to be the situation with UMTS (the 3rd generation system, still under standardisation in some aspects, but already in trial/commercial operation in some European countries, and in full commercial operation in Japan), due to its importance to European industry. As a consequence, R&D continues to be a key factor, and issues related to the next generation of mobile and wireless systems, dealing with broadband multimedia communications (with bandwidths, hence, data rates, much larger than the 3rd generation ones), are already being addressed by a large number of people in the European R&D community. It has also been recognised, for many years now, that better and faster results are achieved by joint efforts at the European level, rather than countries conducting their national programmes individually. The RACE, ACTS [1], IST [2] and COST [3] (European Cooperation in the Field of Scientific and Technical Research) frameworks are the result of this recognition, and many projects were, are being, and certainly will be developed in the area of mobile and wireless communications within these frameworks.

The Telecommunications area of COST has already in its curriculum very successful projects, designated as Actions, which dealt with mobile and wireless communications, and have contributed to the development and standardisation of commercial systems:

- 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, [4], which contributed to the deployment of GSM1800 and to the development of DECT, HIPERLAN 1 and UMTS;
- COST 259, "Wireless Flexible Personalised Communications", Dec. 1996 – Apr. 2000, [5], 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.

For example, COST 207 provided the channel model for GSM, COST 231 defined propagation models for the GSM band that are recommended by ETSI and ITU-R, while COST 259 conducted simulations addressing the dispute over the access techniques for UMTS (TDMA versus CDMA), supporting ETSI on its decision, and established the basis for directional channel models. All these Actions have basically addressed the various areas of wireless/mobile communications for the systems already identified, i.e., propagation and channel modelling, radio system and network aspects, modulation and access techniques, antennas (from a system point of view) and diversity issues, channel allocation strategies, cellular planning tools, protocols, and traffic modelling, among others. Each of these projects has published a Final Report, which constitutes the summary of the main results achieved in it [6], [7], [8].

These areas, together with new topics that in the mean time caught the attention of researchers, e.g., especially, MIMO systems, continue to be the main focus of research in mobile and wireless systems addressing broadband multimedia

communications. This constitutes the theme for the current project, COST 273, "Towards Mobile Broadband Multimedia Networks", May 2001 – May 2005 [9], which emerged as a follow-on from the previous projects.

This paper contains a brief overview on COST 273. The following section addresses the objectives of the Action. Subsequently, the organisation and the technical structure of the Action are introduced, and then some topics dealt with in each of the Working Groups are listed. Very brief conclusions are presented at the end.

OBJECTIVES

The main objective is to increase the knowledge on the radio aspects of mobile and wireless broadband multimedia networks, by exploring and developing new methods, models, techniques, strategies and tools towards the implementation of 4th generation mobile and wireless communication systems. It considers frequencies ranging from the upper UHF up to millimetre waves, and data rates essentially higher than 2 Mb/s. As a secondary objective, it is intended that it should continue to play a supporting role similar to the one played by the previous Actions in the mobile and wireless communications area. That is, besides giving inputs to the development of systems beyond the 3rd generation, it is also expected that it will contribute to the deployment of systems that are more or less standardised, like UMTS and WLANs.

The activities carried out in the Action will bring benefits not only at a national level but also at the European one. It is expected to maintain, and even increase, the industrial competitiveness of European industry in the mobile and wireless communications area, due to the work on future systems and the assistance in the deployment of existing ones. It includes research work that ranges from the fundamentals of the systems to the more applied aspects, and it addresses the various aspects of mobile and wireless systems, therefore, creating conditions for multidisciplinary work. It brings direct benefits to the countries and institutions involved, since this pan-European activity enables the exchange of information at a level that would not be possible for the researchers individually, just by attending conferences or by conducting bilateral exchanges. It helps to improve the quality and to speed up the results of the performed R&D work in the very competitive area of mobile and wireless communications, because of the permanent collaboration and exchange of information. It supports European standardisation bodies in their work at the more international level, by creating inputs leading to better technically supported decisions: Last, but not the least, the grouping of such a large community of researchers contributing to standardisation provides further stimulation to the growth of the mobile and wireless communications market.

ORGANISATION

The Action is structured into Working Groups (WGs), 3 in total, within which the technical work is carried out:

- WG 1 - Radio System Aspects,
- WG 2 - Propagation and Antennas,
- WG 3 - Radio Network Aspects.

Sub-Working Groups (SWGs) have also been created, devoted to more specific topics, at the moment, being as follows:

- SWG 2.1 - MIMO channel model,
- SWG 2.2 - Antenna performance of small Mobile terminals,
- SWG 2.3 - Channel Measurements,
- SWG 3.1 - Mobile radio networks reference scenarios.

The description of their activities is presented in the next section, Figure 1 showing their interrelation.

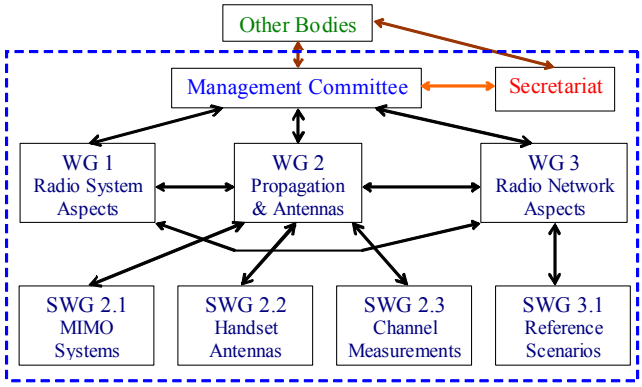

Figure 1 Organisation of COST 273.

The leadership of the Action, and of the several WGs and SWGs, is spread over various countries:

- Chairman – Luis M. Correia, Instituto Superior Técnico / Technical University of Lisbon, Lisbon, Portugal
- Vice-Chairman – Narcis Cardona, Technical University of Valencia, Valencia, Spain
- WG 1 Chairman – Alister Burr, University of York, York, UK
- WG 2 Chairman – Ernst Bonek, Technical University of Vienna, Vienna, Austria
- WG 3 Chairman – Roberto Verdone, CNIT at the University of Bologna, Bologna, Italy
- SWG 2.1 Chairman – Andreas Molisch, University of Lund, Lund, Sweden
- SWG 2.2 Chairman – Gert Pedersen, Aalborg University, Aalborg, Denmark
- SWG 2.3 Chairman – Pertti Vainikainen, Helsinki University of Technology, Helsinki, Finland
- SWG 3.1 Chairwoman – Silvia Ruiz, Polytechnical University of Catalonia, Barcelona, Spain

The Management Committee and the WGs meet three times per year [9], meetings circulating among the participating European countries; SWGs also meet at the same time as the WGs, but additional meetings can occur. Besides administrative matters, which occupy a small fraction thereof, essentially these meetings are used to present and discuss Temporary Documents (TDs), which consist of the technical contributions of each participating institution. A full list of TDs, with abstracts, is available in [9]. Although the documents themselves are only available inside the project, authors can be addressed directly to release their own TDs. Usually, meetings begin with one or two half day tutorials, given by participants, on topics dealt within the project; up to now, the following areas were addressed: "*Channel Modelling*", "*Game Theory*", "*Propagation Models*", "*Radio resource management*", "*Iterative (turbo) MIMO equalisation techniques*", "*MIMO channel modelling revisited*", "*Turbo-codes and Turbo Processing*". At the end of each project year, a workshop is held, many times in conjunction with other Actions or other bodies, hence, putting together people with interest in a given research area. Previous workshops were devoted to "*Opportunities of the multidimensional propagation channel*" [10], "*Broadband wireless local access*" [11] and "*Antennas and Related Systems Aspects in Wireless Communications*" [12] (this last one, co-organised with COST 284).

At present, 26 European countries have signed the Memorandum of Understanding (MoU), which makes of COST 273 one of the largest Actions in the COST framework: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, The Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, UK, Yugoslavia. Additionally, a few selected highly renowned institutions from 4 countries outside Europe are also participating: Canada, Japan, Taiwan, and United Stated of America. A total of 112 institutions [9] are actively contributing, roughly involving around 400 researchers. Institutions from one of the countries that have signed the MoU are welcome to participate, but they are required to contribute with at least a TD in one meeting per year; in the case of institutions from other countries, their participation is also welcome, but this needs the approval of the Management Committee, and they are required to contribute with at least a TD in two meetings per year.

The regular meetings and the exchange of newest results, sometimes even such that need substantiation before publication, have lead to the spirit of "competitive co-operation". Each group wants to present their latest results on pressing issues ahead of others. Many new ideas spring up just from the comparison of methods.

Basically, the project does not involve any funding to participating institutions. The funding allocated to the Action is essentially to support the secretariat, the annual workshop, and travel expenses in certain circumstances (for a limited number of participants to attend the Management Committee meetings and to exchange researchers between institutions). This means that the results presented at the project, travel to the meetings for most researchers, and so on, are funded by other sources, at the institutions responsibility.

TECHNICAL ISSUES

The technical work is carried out in the Working Groups, as previously mentioned. A description of the topics addressed in each one follows.

The specific areas dealt with by Working Group 1 include:

- MIMO transmission techniques, including space-time codes and spatial multiplexing and their performance on realistic propagation channels;
- smart antennas and beamforming;
- turbo (iterative) processing techniques, and other approaches, applied to equalisation, synchronisation and channel estimation, and multi-user detection;
- multi-user systems and access techniques, including WCDMA;
- development of OFDM systems and techniques, including MC-CDMA;
- modulation and coding techniques, including turbo-codes;
- adaptive systems and adaptation algorithms;

- implementation issues, including computational complexity, and the effect of non-linear amplifiers.

Working Group 2 addresses mainly the following topics:

- physical propagation mechanisms for mobile/wireless radio, at the specific bands of micro- and millimetre-waves; questions of modelling, characterisation and measurements of scattering effects, relevant multipath components, path correlation, path parameters variability, diffraction, and materials characterisation are investigated as well;
- modelling techniques for the characterisation of propagation (e.g., deterministic approaches based on ray-tracing, statistical characterisation, and neural networks), and their assessment by measurements, having in mind signal estimation for planning purposes, and taking into consideration time-variant effects, system bandwidth, elevations and large scale effects; fading prediction over more than a wavelength ahead is a fairly new topic that promises major steps forward in adaptive modulation;
- modelling, evaluation by measurements and implementation in simulators of directional wideband radio channels for adaptive antennas, addressing the various aspects like direction-of-arrival and angular power spectrum, polarisation, and statistical approaches including time-variant effects, including as well the double-directional approach applicable to MIMO systems;
- analysis of propagation channels for the specific scenarios of mobile to mobile and point-to-multipoint; modelling of adaptive antennas radiation, characterisation of various antenna array geometries, and antenna array calibration, accompanied by multi-sensor measurements, and impact on system performance;
- characterisation of handset antennas, including the comparison of the antenna loss in real scenarios with standard ones and 3-dimensional radiation pattern measurements (both spatial distribution and polarisation characteristics) in real indoor and outdoor scenarios and also in the presence of humans and/or phantoms in anechoic chambers.

As for Working Group 3, its areas of activity encompass:

- analysis of techniques for radio network optimisation, not specifically addressing a particular air interface standard, but aiming at the provision of general results;
- development of general methodologies, both analytical and simulative, for the performance evaluation of radio networks; development of simulation techniques at system level for wireless cellular networks, including suitable interfaces with the link level;
- investigation of advanced radio network planning aspects, like automatic reconfiguration and planning using operational information, definition and analysis of network quality concepts (including quality of service), and enhancements by using adaptive antennas;
- investigation on aspects of network optimisation in WCDMA (both TDD and FDD) systems, and on capacity-related issues, namely optimisation of downlink signalling power, soft handover parameters, power control, dynamic channel allocation, mobility management, MAC protocols, link layer control, scheduling, etc.;
- analysis of traffic models and scenarios for 3G (WCDMA) and B3G networks, new applications, and their impact on the design of wireless transmission techniques;
- study of the performance of MAC and networking techniques for packet radio networks, in Wireless LANs or Personal Area Networks, using IEEE802.11 or Bluetooth;
- investigation of networking issues in self-organising networks, such as ad hoc networks.

The purpose of Sub-Working Group 2.1 is to establish a model of the wireless channel that is suitable for MIMO systems. This is the natural continuation of previous COST channel modelling activities. It is planned to establish a suitable categorisation of channels for macro-, micro-, and pico-cellular environments. It will then establish a generic framework for MIMO channels, characterised by a set of parameters. Parallel to this activity, measurement results of the MIMO channel impulse responses will be collected from the participants of the group. By using those measurements, as well as other data available in the literature, suitable values for the parameters in the different environments will be determined.

The aim of Sub-Working Group 2.2 is to establish measuring techniques for antennas on small mobile terminals, as well as establishing performance relations by including information from the propagation environment where the terminals are used. The group is investigating how to make reliable measurements of mobile phones including both transmitter and receiver, as well as the influence from the user. Methods for including the influence of the propagation channel are based on the Mean Effective Gain and special focus is on UMTS terminals.

Sub-Working Group 2.3 aims at developing propagation channel measurement techniques and providing measurement results to support especially the channel modelling work in SWG 2.1, but also the development of future mobile antennas, such as diversity or multi-antenna systems in SWG 2.2. The measurement work includes co-operation in the use of channel measurement systems and their results, and the development of new measurement systems. It is intended to provide measurement results especially in new areas like MIMO and UWB channels.

Finally, Sub-Working Group 3.1 focuses on the definition of some common Reference Scenarios to be used when performing the numerical assessment of radio access techniques, with reference both to Radio Network Planning (RNP) and Radio Resource Management (RRM). Thus, the scope is to provide a means to make more comparable the results

of the different approaches used when evaluating RNP or RRM strategies. Owing to the complexity of these Reference Scenarios, 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 it easy to interpret the results, and real-world based scenarios, where some data is taken from the real world, thus making their definition (and use) more complex but providing the possibility to test radio network algorithms under more realistic conditions. The Reference Scenarios have to satisfy a number of requirements in order to be of practical relevance. Some of them are: ease of use, limited number of cases, defined Interfaces between different parts of the Scenarios, extensibility, and independence of commercial realities. The initiative created in SWG 3.1 towards the standardisation of scenarios has been designated as MORANS (MObile Radio Access Network reference Scenarios).

Working Group 1 has considered primarily the physical layer of radio systems, including in particular transmission and signal processing techniques. In the past three years of the Action, there have been two dominant themes: MIMO systems and iterative ("turbo") techniques. Work on MIMO systems and space-time coding have included the application of coded modulation, application to CDMA, OFDM and MC-CDMA, adaptive MIMO systems and system capacity, among other issues. Iterative techniques have been applied to a wide range of signal processing functions, including detection, equalisation, synchronisation and channel estimation, MIMO detection and multi-user detection. Joint sessions with other Working Groups have encouraged collaboration between signal processing specialists and propagation and network experts: joint sessions with Working Group 2 have considered MIMO channel modelling and the capacity of the MIMO channel and fading forecasting for adaptive systems, among other subjects, and with Working Group 3 sessions have considered the evaluation of network capacity and the interaction of physical and higher layers in standards such as UMTS FDD and HSDPA.

Working Group 2 dealt with several topics already. A thorough investigation about the keyhole effect in MIMO channels revealed that such effects are extremely hard to construct experimentally, pointing to a gross overestimation of this phenomenon in actual propagation situations. Recent contributions yielded valuable information about actual scattering objects (resulting in "clusters") by combining UWB measurements with DOA and DOD information. A totally new concept by a real-time hardware emulation of the directional radio channel on the basis of the COST 259 model has been introduced as well. The popular ´Kronecker` model has been shown to be insufficient for indoor, at least, where coupling of directions of arrival and directions of departure do occur; this has been measured in indoor environments at 2.4 and 5.2 GHz. A novel MIMO modelling framework has sprung up from these measurements, extending the Kronecker model to account for the correlation between TX and RX arrays, and serving as a framework for algorithmic design; as an extension of the “virtual c channel representation” of Sayeed, it decomposes the MIMO channel in a matrix product of the matrix-sized eigenmodes and a coupling matrix in between; the novelty being the use of the RX and TX correlation matrices as basis functions, leading to an intuitively appealing interpretation of the MIMO channel. World-leading MIMO measurements of unprecedented accuracy and detail are being reported in COST meetings, some of them yielding multi-dimensional characterisation of the MIMO channel in real time. Also, SWG 2.2 is driving the international standards for testing of handset antennas in a true, live environment. This has become pressing need because of the requirement to for manufacturers to state the SAR value on the handset. One can reduce the SAR by making the antenna less efficient, which is not the goal of advanced antenna design, of course. SWG 2.2 is in the process of finding a good and fair description of how efficient an antenna is when it is connected to handset in practical use.

Working Group 3 addressed, during the first three years activity, issues related to Third Generation systems and beyond, Wireless Local and Personal Area Network. The main focus was on the Radio Network Planning and Resource Management techniques, aiming at optimising the use of the radio spectrum in cellular systems like WCDMA. In this context, interesting achievements have been obtained regarding pilot downlink power optimisation and the role of soft handover on network capacity. These results have also been reported to the scientific public literature after suitable discussion within the WG. Another relevant result has been achieved within SWG3.1 (the MORANS initiative), which generated an XML-based database of reference scenarios useful for the comparison of the performance of RRM techniques under common scenarios; this result was obtained only very recently, and for this reason it will be used in the forthcoming final year of COST273.

CONCLUSIONS

This paper presents a brief overview of the technical activities addressed by COST 273. After an Introduction, where previous COST Actions in the area of mobile and wireless communications are listed, the Objectives of the Action are shown. The internal technical structure of the Working Groups, and their Sub-Working Groups, is addressed, and many of the topics dealt with within each one are listed.

By the time this article is being written, the preparation of the final report has already started, being expected that it will be available by mid 2005. It will include the main results of the project, e.g., a model for MIMO channels assessed by

measurements, references scenarios from MORANS for radio network simulation and evaluation, and a proposal for a procedure for the test of handset antennas.

Detailed information on COST 273 can be found at http://www.lx.it.pt/cost273.

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