COST Domain Committee "Information and Communications Technology" (DC-ICT)

COST Action 289

Spectrum and Power Efficient Broadband Communications

FINAL REPORT

Period: from 24 April 2003 to 30 June 2007

Start date of the Action: 24 April 2003 Last update: 13 August 2007

1. OVERVIEW: ACTION IDENTIFICATION DATA

COST Action 289
Title: Spectrum and Power Efficient Broadband Communications

DC Recommendation: 8 October 2002
CSO Approval: 2 December 2002
Start date: 23 April 2003
Duration: 48 months
Extension:
End date: 22 April 2007

First MC meeting: 24 March 2003
Last MC meeting: 11-13 April 2007
Final Report: 06 August 2007
Evaluation Report:
TC Evaluation:

Number of signatories: 19
Signatories and date of signature:

Belgium	05/08/2003	Confirmed
Bulgaria	04/04/2003	Confirmed
Czech Republic	05/08/2003	Confirmed
France	05/08/2003	Confirmed
Germany	02/04/2003	Confirmed
Greece	30/09/2003	Confirmed
Hungary	28/03/2003	Confirmed
Italy	05/08/2003	Confirmed
Malta	11/03/2005	Confirmed
Norway	05/08/2003	Confirmed
Portugal	21/09/2004	Confirmed
Romania	23/06/2004	Confirmed
Serbia and Montenegro	20/11/2003	Confirmed
Slovakia	14/04/2003	Confirmed
Spain	25/09/2003	Confirmed
Sweden	12/08/2003	Confirmed
Switzerland	23/05/2003	Confirmed
Turkey	23/04/2003	Confirmed
UK	18/10/2004	Confirmed

Institutes of non-COST countries: None
Area: Mobile Communications
Action web site: http://cost289.ee.hacettepe.edu.tr
Chairperson: Prof. Dr. Mehmet Safak

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TC Rapporteur: Mr. Hans Schmiedel
External Evaluator: Prof. Oßwald Rüger

1. OBJECTIVES

The requirements for higher user mobility and for ever increasing data rates seem to act as two major drivers of future communication systems. Based on this observation, the main objective of this Action is to increase the capacity of communication systems with constraints on the transmission bandwidth and the transmitter power, bearing in mind the cost effectiveness and the practicality of the solution. This imposes serious requirements on communication systems calling for higher data rates, higher mobility and, at the same time, a less hazardous electromagnetic environment. To achieve this goal, existing and innovative communication techniques and systems need to be investigated from the viewpoint of the bandwidth and the power efficiency.

This project aims to contribute to the realization of spectrum- and power-efficient integrated multimedia communications, thus to minimize the bandwidth requirements for high data rate services. Reciprocally, the requirements on the transmit power will be reduced for a given transmission bandwidth. The resulting benefits will include the provision of higher data rates, larger coverage areas, higher mobility to the users, and longer battery life for mobile terminals. All these will contribute to the provision of better QoS and cost effective services. The systems thus designed will also contribute to the creation of a less polluted electromagnetic propagation environment. Consequently, one may expect reduced electromagnetic compatibility (EMC) problems with other electronic systems and significant reduction in hazardous radiation effects to biological systems. The outcome of the Action is believed to provide valuable contribution to the literature and the technology in the related areas.

2. TECHNICAL DESCRIPTION AND IMPLEMENTATION

The philosophy of the Action is based on close co-operation between the scientists and engineers from the telecommunication industry and the academia. In agreement with the above-cited objectives, the research efforts will be focused on the problems discussed below.

2.1 Working Groups

The research activities of this Action are conducted in two Working Groups (WG's):

a) WG1: Information Theoretical Description of Radio Systems

The aim of WG1 is to provide an analytical description of mobile systems and related architectures, and to carry out detailed analyses of modern communication systems. The emphasis will be on mathematical studies and simulations rather than on the implementation issues. The output of WG1 may also be used as an input to WG2.

A list of research areas of the WG1 includes, but not limited to:

- *Spectral efficiency and power efficiency*
- *Channel capacity*
- *User capacity*
- *Modulation*
- *Coding*

b) WG2: Communications Techniques and Systems

The objective of WG2 is to study the implementation of techniques and algorithms for increasing the data rates, the user mobility, the reliability as well as the power- and spectrum-efficiency of communication systems.

The research activities of the WG2 include, but not limited to:

- *Adaptive transmission techniques*
- *Software defined radio*
- *Adaptive/reconfigurable networks*
- *Multicarrier systems*
- *Multiple access techniques*
- *Multiuser detection*
- *Multiple-input multiple-output (MIMO) systems*

The two WGs define the framework of the research activities proposed in this Action. Management Committee (MC) decided to monitor the scientific activities in the two WGs in plenary sessions. Consequently, the MC has decided not to appoint heads to these WGs.

2.2 Project Groups

A COST Action is believed to provide a platform not only for the presentation of individual research results of the participants but should also act as a means to create synergy in coordinated and cooperative research efforts in order to find coherent and practical solutions to the problem formulated in the MoU.

Accordingly, the MC decided to form the following three project groups, with active participation of a number of institutions listed below. The detailed description of these projects is given in Section 4. RESULTS.

a) Pervasive wireless access for 4G
***Coordinator*:** Prof. Armin Wittneben, ETH Zurich
***The participating organizations*:** ETH Zurich, Hacettepe University, Norwegian University of Science and Technology, University of Ulm, Budapest University of Technology and Economics, University Carlos III of Madrid.

b) Wide are coverage and high mobility access systems for 4G
***Coordinator*:** Prof. Arne Svensson, Chalmers University of Technology
***The participating organizations*:** Chalmers University of Technology, University of Florence, Ramon Llull University, CEI-LETI, University Carlos III of Madrid, Hacettepe University, TU Kosice, Czech Academy of Science, Norwegian University of Science and Technology, DLR.

c) Software defined radio
***Coordinator*:** Prof. Sandor Imre, Budapest University of Technology and Economics.
***The participating organizations*:** Budapest University of Technology and Economics, University Carlos III of Madrid, Ramon Llull University, Universitat Politècnica de Catalunya, University of Athens.

The above research projects were finalized during the 4th MCM, held in Zurich, 15-16 March 2004. Each researcher is free to choose his/her own individual research area, within the framework of the project. The researchers participating to the above projects decided to cooperate closely and concentrate their efforts to investigate in detail and bring coherent solutions to the formulated problems.

It was desired to organise an inauguration meeting for the above three project groups with the participation of young researchers. However, in view of the large numbers of participation in each of the projects, the project coordinators prepared a description of their project programmes and disseminated these programmes to the members.

Some of the researchers visited the project coordinators in STSMs for better coordination of the research efforts. These researchers are also encouraged to attend the Workshops organized in order to increase their awareness about the project, to present their research results and for further coordination and cooperation.

Three separate *e-mail groups* are formed for the three research projects, namely *Pervasive Wireless Access for 4G*, *Wide Area Coverage Systems with High Mobility for 4G*, and *SDR*. These e-mail groups are aimed for exchange of information and documents between the young researchers directly involved in the projects and to provide a common platform for discussing the outstanding items.

3. PARTICIPATION AND COORDINATION

3.1 Management Committee

Chairman:
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Members:

Prof. **H. Rohling**, Technical University of Hamburg-Harburg, Germany
Prof. **A. Wittneben**, Swiss Federal Institute of Technology, Switzerland:
Prof. **J. Lindner**, University of Ulm, Germany
Prof. **H. Vinck**, University of Essen, Germany
Prof. **A. Svensson**, Chalmers University of Technology, Sweden
Dr. **S. Kaiser**, German Aerospace Centre, DLR, Germany
Prof. **L. Vandendorpe**, Universite Catholique de Louvain, Belgium
Dr. **M. Dangl**, University of Ulm, Germany
Prof. **A. Polydoros**, University of Athens, Greece
Researcher **K. Nikitopoulos,** University of Athens, Greece
Prof. **D. Kocur**, Technical University of Kosice, Slovakia
Prof. **A. Ahlen**, Uppsala University, Sweden
Prof. **L. Pap**, Budapest University of Technology and Economics, Hungary:
Prof. **S. Imre**, Budapest University of Technology and Economics, Hungary
Dr. **G. Jeney**, Budapest Un. of Technology and Economics, Hungary
Prof. **R. Fantacci**, University of Florence, Italy
Dr.. **D. Tarchi**, University of Florence, Italy
Prof. **J. L. Pijoan**, Ramon Llull University, Spain
Dr. **J. P. Romero**, Polytechnic University of Catalunya, Spain
Researcher **F.A. Freixer**, Polytechnic University of Catalunya, Spain
Dr. **A. Garcia-Armada**, University Carlos III of Madrid, Spain
Researcher **M. P. S. Fernandez**, University Carlos III of Madrid, Spain
Dr. **V. P. G. Jimenez**, University Carlos III of Madrid, Spain
Prof. **M. Safak**, Hacettepe University, Turkey
Researcher **G. Pay**, Hacettepe University, Turkey
Dr. **G. Meyer**, Swiss Federal Institute of Technology, Switzerland
Prof. **G. E. Oien**, Department of Telematics, NTNU, Norway
Prof. **K. J. Hole**, Department of Telematics, NTNU, Norway
Dr. **J. Simsa**, Academy of Sciences, Czech Republic
Prof. **G. Iliev**, Technical University of Sofia, Bulgaria
Prof. **V. Bota**, Technical University of Cluj-Napoca, Romania
Prof. **A. de Sabato**, Politchnical University of Timisoara
Prof. **H. Sari**, SUPELEC, France
Dr. **R. Visoz**, France Telecom R& D, France
Prof. **D. Bajic**, University of Novi Sad, Serbia
Dr. **W. Teich**, University of Ulm, Germany
Dr. **U.C. Fiebig**, DLR, Germany
Dr. **C. Toker**, Hacettepe University, Turkey
Dr. **S. Mayrargue**, CEA-LETI, France
Dr. **K. Hamdi**, UMIST, UK
Dr. **S. Morosi**, University of Florence, Italy
Dr. **A. Berthet**, SUPELEC, France
Dr. **M. Drutarovsky**, Technical University of Kosice, Slovakia
Dr. **E. Alsusa**, University of Manchaster, UK
Dr. **J. Azzopardi**, Acrosslimits, Malta

Prof. **S. Robert**, EIVD, Switzerland
Prof. **A. Safak**, Baskent University, Turkey
Dr. **E. Aktas,** Hacettepe University, Turkey
Researcher **S. Plass**, German Aerospace Centre, DLR, Germany
Researcher **S. Sand**, German Aerospace Centre, DLR, Germany
Researcher **D. Vukobratovic**, University of Novi Sad, Serbia
Dr. **F. Chiti**, University of Florence, Italy
Researcher **G. Mennuti**, University of Florence, Italy
Researcher **S. Wendt**, France Telecom R&D, France
Researcher **P. Katsis**, Aristotle University of Thessaloniki, Greece
Researcher **G. Papadopoulos**, Aristotle University of Thessaloniki, Greece
Researcher **S. Hasimoglu-Ertas**, Hacettepe University, Turkey
Researcher **F. Balasz**, Budapest Un. of Technology and Economics, Hungary
Researcher **G. Rabai**, Budapest Un. of Technology and Economics, Hungary
Researcher **C. Vilella**, Ramon Llull University, Spain
Researcher **S. Berger**, ETH Zurich, Switzerland
Dr. **I. Hammerstroem**, ETH Zurich, Switzerland
Researcher **B. Rankov**, ETH Zurich, Switzerland
Researcher **J. Cizova**, Technical University of Kosice, Slovakia
Dr. **P. Galajda**, Technical University of Kosice, Slovakia
Researcher **V.Senk**, University of Novi Sad, Serbia and Montenegro
Researcher **S. Kethulle**, Norwegian Univ. of Science and Technology, Norway
Researcher **I. Safak**, Hacettepe University, Turkey
Researcher **M. Cakir**, Hacettepe University, Turkey
Researcher **J. Krajnak**, TU Kosice, Slovakia
Researcher **X. Reves**, Polytechnic University of Catalunya, Spain
Researcher **P. Bergada**, Ramon Llull University, Spain
Researcher **Z. Andreas**, NKUA University of Athens, Greece
Dr. **M. Varga**, Technical University of Cluj-Napoca, Romania
Researcher **L.Wischhof**, TU Hamburg, Germany
Dr. **P. Fazekas** Budapest Univ. of Technology and Economics, Hungary
Researcher **V. Hassel**, Norwegian Univ. of Science and Technology, Norway
Researcher **A. Papaioannou**, Aristotle University of Thessaloniki, Greece
Researcher **P. Zsolt**, TU Cluj-Napoca, Romania
Researcher **R. Aquilue**, Ramon Llull University, Spain
Researcher **R. M. Alsina**, Ramon Llull University, Spain
Researcher **I. Gutierrez**, Ramon Llull University, Spain
Researcher **V. Markovic**, Polytechnic University of Catalunya, Spain
Researcher **F. Adelantado**, Polytechnic University of Catalunya, Spain
Researcher **L. Alonso**, Polytechnic University of Catalunya, Spain
Researcher **I. Cosovic**, DLR, Germany
Researcher **A. Dammann**, DLR, Germany
Researcher **S. Brandes**, DLR, Germany
Researcher **S. Gligorevic**, DLR, Germany
Researcher **E. Haas**, DLR, Germany
Researcher **D. Yacoub**, University of Ulm, Germany
Researcher **I. Perisa**, University of Ulm, Germany
Researcher **W. Zhang**, University of Ulm, Germany
Researcher **A. Silva**, Institute of Telecommunications, Portugal
Researcher **C. Stefanovic**, University of Novi-Sad, Serbia

Researcher **M. Dikmen**, Hacettepe University, Turkey
Researcher **Ö. Karabacak**, Hacettepe University, Turkey
Researcher **K. Baumgartner**, University of Applied Sciences (EIVD)
Researcher **C. Stefanovic**, Univ. of Novi Sad, Serbia
Researcher **M. Deumal**, Ramon Llull University, Spain
Researcher **M. Wetz**, University of Ulm, Germany
Researcher **C. Riberio**, University of Aveiro, Portugal
Dr. **A. Behravan**, Chalmers University of Technology, Sweden
Researcher **M. Stemick**, Technical University of Harburg-Hamburg, Germany,
Prof. **M. J. Fernandez-Getino Garcia**, University of Carlos III of Madrid, Spain
Researcher **M. Karaman-Colakoglu**, ASELSAN Inc., Turkey
Prof. **A. Gameiro**, University of Aveiro, Prortugal
Dr. **V. Crnojevic**, University of Novi Sad, Serbia
Dr. **C. Mutti**, ETH Zurich, Switzerland

3.2 Participating Institutions

Belgium	**Universite Catholique de Louvain**
Bulgaria	**Technical University of Sofia**
Czech Republic	**Academy of Sciencies**
France	**Supelec**
	France Telecom R&D
	CEA-CETI
Germany	**Technical University of Hamburg-Harburg**
	University of Ulm
	University of Essen
	German Aerospace Centre, DLR
Greece	**University of Athens**
	Aristotle University of Thessaloniki
Hungary	**Budapest Univ. of Technology and Economics**
Italy	**University of Florence**
Malta	**AcrossLimits**
Norway	**Department of Telematics, NTNU**
Portugal	**Uni. of Aveiro, Inst. of Telecommunications**
Romania	**Technical University of Cluj-Napoca**
	Politechnic University of Timisoara
Serbia and Montenegro	**University of Novi Sad**
Slovak Republic	**Technical University of Kosice**
Spain	**Ramon Llull University**
	Polytechnic University of Catalunya
	University Carlos III of Madrid
Sweden	**Chalmers University of Technology**
	Uppsala University
Switzerland	**Swiss Federal Institute of Technology, Zurich**
	University of Applied Sciences (EIVD)
Turkey	**Hacettepe University**
United Kingdom	**University of Manchester**

3.3 Meetings of the Management Committee

Inaug. MCM	24 March 2003, Brussels, Belgium
2. MCM	3-4 July 2003, Hamburg, Germany
3. MCM	30-31 October 2003, Kosice, Slovak Republic
4. MCM	15-16 March 2004, Zurich, Switzerland
5. MCM	7-9 July 2004, Budapest, Hungary (jointly with 1st Workshop)
6. MCM	28-29 October 2004, Barcelona, Spain
7. MCM	7-8 March 2005, Oberpfaffenhofen, Munich Germany
8. MCM	6-8 July 2005, Antalya, Turkey (jointly with 2nd Workshop)
9. MCM	3-4 November 2005, Madrid, Spain
10. MCM	23-24 March 2006, Novi Sad, Serbia and Montenegro
11. MCM	12-14 July 2006, Aveiro, Portugal (jointly with 3rd Workshop)
12. MCM	30-31 October 2006, Florence, Italy
13. MCM	11-13 April 2007, Gothenburg, Sweden (jointly with 4th Workshop)

3.4 DC-ICT Annual Review Meetings (ARM)

1. ARM	3-5 June 2003, Dubrovnik, Croatia
2. ARM	30 June-2 July 2004, Bucarest, Romania
3. ARM	28 June-1 July 2005, Vitznau, Switzerland
4. ARM	21-22 November 2006, Helsinki, Finland

3.5 Short-Term Scientific Missions

The list of STSMs during the lifetime of the Action is as follows:

- **Wide Area Coverage for 4G:**

  Host: Prof. Arne Svensson, Chalmers University of Technology, Göteborg
  Visitors:
  Marc Deumal (Ramon Llull University, 13.9.2004 - 29.11, 2004),
  Victor Pedro Gil-Jimenez (Univ. Carlos III of Madrid, 4.9.2004-9.12, 2004),
  Simon Plass (DLR, 20.9.2004 - 24.9. 2004),
  Jozef Krajnak (TU Kosice, 18.9.2004 - 3.10. 2004),
  Serap Hasimoglu-Ertas (Hacettepe University, 20.9.2004 - 17.12, 2004)

  Host: Prof. Hermann Rohling, TUHH, Hamburg, Germany
  Visitor:
  M.Varga (Technical University Cluj-Napoca, Romania, 13.06.2005-24.06.2005)

  Host: Prof. J.L. Pijoan, Ramon Llull University, Barcelona
  Visitors:
  Ali Behravan (Chalmers University of Technology, 20 Feb.-12 March 2006)
  Pavol Pavelka (Technical University of Kosice, 5-9 June 2006)

  Host: Prof. D. Kocur, Technical University of Kosice, Kosice, Slovak Republic

Visitor:
Marc Deumal (Ramon Llull University, Barcelona, 13-20 December 2006)

- **Pervasive Access for 4G:**

  Host: Prof. Armin Wittneben, ETH Zurich
  Visitor: Doris Yacoub (University of Ulm, 11 -17 June 2006)

  Host: Dr. Simone Morosi, University of Morosi, University of Florence
  Visitor: M. Luz Pablo Gonzales (University of Carlos III, Madrid, 1 October 2006 - 30 November 2006)

- **Software Defined Radio:**
  Host: Polytechnic University of Catalunya (UPC), Barcelona
  Visitors:
  Ferenc Balazs (BUTE, 24.10.2004 – 4.11, 2004)
  Pavol Galajda (TU Kosice, 18.10.2004 – 22.10, 2004)

In order to bring a uniformity to the financial supports by the STSMs, the MC decided to follow the following payment scheme: The cost of plane ticket will be deducted from 2500 €, which is the maximum financial support for an STSM, and the remaining amount will be divided into 30 days, which represents the duration of the maximum stay in a STSM. This will give the amount of financial support per day. The total financial support will be given by the sum of the *cost of the transportation ticket* and *the number of nights spent in STSM* times *the daily financial support*. The Chairman is authorized to increase or decrease the amount of daily support thus found up to 20% depending on the living standards in the host country. The researchers, who are supported by the STSM programme, are strongly recommended to report to the MC about the scientific results of their STSMs.

3.5.1 Publications Resulting From STSMs

The current list of publications resulted from the STSMs is given below, where the name of the author supported by the STSM program is shown in bold. Note that the researchers supported by the STSM program are all Ph.D. students and they mostly completed their Ph.D.'s in the cooperative scientific environment of the COST Action 289.

- **S. Plass**, S. Sand, M. Sternad and A. Svensson, *High Spectral Efficient and Flexible Next Generation Mobile Communications*, presented in 4th COST Workshop held in Gothenburg during 11-12 April 2007, and accepted for publication for the Special COST289 Issue of Wireless Personal Communications, early 2008.

- **V. P. Gil Gimenez**, T. Eriksson, A. G. Armada, M. J. Fernandez-Getino Garcia, T. Ottoson and A. Svensson, *Methods for Compression of Feedback in Adaptive Multicarrier 4G Systems*, presented in 4th COST Workshop held in Gothenburg during 11-12 April 2007, and accepted for publication for the Special COST289 Issue of Wireless Personal Communications, early 2008.

- **M. Deumal**, J. L. Pijoan, I. Gutiérrez, **A. Behravan**, *Peak Reduction of Multicarrier Systems by Controlled Spectral Outgrowth*, Proc. IEEE International conference on Acoustics, Speech and Signal Processing (ICASSP 2006), May 2006, Toulouse.

- **M. Deumal**, J. L. Pijoan, **A. Behravan** and T. Eriksson, *Evaluation of Performance Improvement Capabilities of PAPR-Reducing Methods*, presented in 4th COST Workshop held in Gothenburg during 11-12 April 2007, and accepted for publication for the Special COST289 Issue of Wireless Personal Communications, early 2008.

- **J. Krajnak**, P. Pavelka, D. Kocur, P. Galajda, **M.Deumal** and J. L. Pijoan, *Multi-user Detection of Nonlinearly Distorted MC-CDMA Symbols by Microstatistic Filtering*, presented in 4th COST Workshop held in Gothenburg during 11-12 April 2007, and accepted for publication for the Special COST289 Issue of Wireless Personal Communications, early 2008.

4. SCIENTIFIC RESULTS

Please see Annex A for details.

5. DISSEMINATION OF RESULTS

5.4 Presentations in MCMs and Workshops

The number of participants, presentations and tutorial made during the MCMs is listed below:

MCM	Participants	Presentations	Tutorials
1st MCM, Brussels, 24 March 2003	12		
2nd MCM, Hamburg, 3-4 July 2003	16	9	
3rd MCM, Kosice, 30-31 Oct. 2003	25	9	
4th MCM, Zurich, 15-16 March 2004	30	12	
5th MCM and 1st COST 289 Workshop, Budapest, 7-9 July 2004	40	20	4
6th MCM, Barcelona, 28-29 October 2004	30	10	1
7th MCM, 7-8 March 2005, Oberpfaffenhofen/Munich	35	6	1
8th MCM, 6-8 July 2005, Antalya	46	21	4
9th MCM, 3-4 Nov. 2005, Madrid	32	12	1
10th MCM, 23-24 March 2006, Novi Sad	32	12	2
11th MCM, 12-14 July 2006, Aveiro	34	14	4
12th MCM, 30-31 October 2006, Florence	29	10	2
13th MCM, 11-13 April 2007, Göteborg	40	17	5
TOTAL	**401**	**152**	**24**

The following presentations were made during the MCM, excluding the presentations made during the Workshops :

1st MCM, 24 March 2003, Brussels
N/A

2nd MCM, 3-4 July 2003, Hamburg

- B. Chen and H. Rohling, *Joint Layer Optimisation for OFDM Bbased Radio Systems*
- A Garcia-Armada, *OFDM-Based PHY Design for Cross-Layer Optimization: Some Open Issues and Proposed Solutions*
- L. G. Alonso Zarate, *MAC/RLC Protocol Design in Heterogeneous Networks*
- D. Galda and H. Rohling, *A Low Complexity Transmitter Structure for OFDM-FDMA Uplink Systems*
- M. A. Dangle, W.G. Teich, J. Lindner and J. Egle, *Joint Iterative Equalization, Demapping, and Decoding with a Soft Interference Canceler*
- S. Bozay and M. Şafak, *Performance Analysis of Spatial Multiplexing and Maximal Ratio Combining Systems in the Presence of Polarization Diversity*
- A. Svensson, *An OFDM Based Protocol for 4G Downlinks*
- M. Sternad, T. Ottoson, A. Ahlen and A. Svensson, *Attaining Both Coverage and High Spectral Efficiency with Adaptive OFDM Downlinks*
- W. Wang, T. Ottoson, M. Sternad, A. Ahlen and A. Svensson, *Impact of Multiuser Diversity on Adaptive OFDM*

3rd MCM, 30-31 October 2003, Kosice

- H. Vinck, *Pulse Position Access Codes*
- F. Chiti, R. Fantacci, G. Mennuti and D. Tarchi, *A Novel Admission Control Algorithm for UMTS System*
- D. Kocur, J. Cizova, S. Marchevsky, *The Piecewise Microstatistic Multiuser Receiver*
- S. Chtourou, R. Visoz, and A. O. Berthet, *A Class of Low Complexity Equalizer for ST-BICM over MIMO block-fading multipath channel*
- S. Sand, *Two-Dimensional Pilot-Aided Channel Estimation for a Broadband MC-CDMA System with High Mobility*
- S. Mayrargue, *MC-CDMA vs DS-CDMA*
- P. Svac, M. Piekov, *CC-CDMA for B3G Wireless Communications: An Overview and Some Open Issues*
- H. Rohling, *Decision Directed Channel Estimation in OFDM based Systems*
- A. Svensson, *Joint Project on "Wide Area Coverage on High Mobility Access Systems for 4G"*

4th MCM, 15-16 March 2004, Zurich

- G. Jeney, J. Levendovszky, S. Imre and L. Pap, *Quadratic Optimization with Stochastic Recurrent Neural Networks*
- S. Plass, *Rank Codes for OFDM*
- D. Vukobratovic, *On BER estimation of IDBP Decoded LDPC Codes*
- S. Wendt, *A Tapped Delay Line Model of Multipath Channel for CDMA Systems*

- F. Chiti, *A Dynamic Rate Allocation Technique for Wireless Communication Systems*
- V. P. Gil Jimenez and A. Garcia Armada, *Bit loading in Hybrid OFDM (H-OFDM)*
- M. S. Fernandez and A. Garcia Armada, *Study of MIMO Channel Capacity for IST METRA Models*
- F. Adelantado, O. Sallent, J. Perez-Romero and R. Agusti, *Traffic Hotspot in UMTS Networks: Influence on RRM Strategies*
- A. Wittneben, *Channel Adaptive Signalling and Scheduling in MIMO Wireless with Low Mobility and Low Channel Rank*
- I. Hammerström, *Joint Cooperative Diversity and Scheduling in Low Mobility Wireless Networks*
- B. Rankov, *Spectral Efficiency of Relay-Assisted MIMO Systems*
- S. Berger, *Radio Access with Cooperative Nodes - The RaCoon Testbed*

5th MCM, 7-9 July 2004, Budapest (jointly with 1st Workshop)

- S. de la Kethulle and G. E. Øien, *Energy-Optimized Coded Modulation for Short-Range Communications on Nakagami-m Fading Channels*
- H. Silalahi and Y. Djamianto and A. Svensson, *UWB Based on Pulsed Multiband*
- A. Svensson, *Performance of Multiband OFDM in IEEE UWB Channel Models*

For other presentations please see the Section 5.2.1 1st COST289 Workshop.

6th MCM, 28-29 October 2004, Barcelona

- S. Morosi, *Reconfigurable Antennas for Future Wireless Communications* (tutorial provided in the framework of NEXWAY, European Network of Excellence)
- H. Vinck, *Coding for a Terrible Channel*
- V. Bota, Z. Polgar and M. Varga, *Performances of LDPC-coded OFDM Transmissions over Fixed and Mobile Channels*
- Z. Polgar, V. Bota and M. Varga, *Correction Capabilities of the Reed-Solomon Codes Decoded with the Guruswami-Sudan Algorithm*
- Y.M. Shobowale and K. A Hamdi, *Accurate BER Analysis of Downlink OFDM systems in a Multi-cell Environment*
- S. Berger, *Experimental Performance Evaluation of Multiuser Zero Forcing Relaying in Indoor Scenarios*
- V. Hassel, M. S. Alouini, D. Gesbert, and G. E. Øien, *Minimizing Feedback Load for Nested Scheduling Algorithms*
- S. Sand, *Iterative Channel Estimation for High Mobility Broadband MC-CDMA System*
- L. Wischhof, *Data Dissemination in Ad-Hoc Networks Based on Inter-Vehicle Communication*
- R. M. Alsina Pagès, *Multiresolution Adaptive Scheme for Acquisition and Detection in a DS-CDMA Digital Receiver in a Multipath Environment*
- R. Fantacci, *Turbo Soft Combining Hybrid ARQ Techniques: Theory and Application to 3G Wireless Networks*

7th MCM, 7-7 March 2005, Oberpfaffenhofen

- S. Kaiser, *Overview on MC-CDMA* (tutorial)
- D. Yacoub, *MC-Cyclic Antenna Frequency Spread: A Novel Space-Frequency Spreading for MIMO-OFDM*
- S. Brandes, *A New Technique for Sidelobe Suppression in OFDM Systems*
- Adao Silva, *Downlink Strategies for TDD MC-CDMA System*
- F. Chiti et al., *Energy Efficient Routing Algorithms for Application to Agro-Food Wireless Sensor Networks*
- D. Bajic, *Short Sequences and Cross-Bifix Analysis*
- V. Bota and M. Varga and Z. Polgar, *Performance Comparison between Different Solutions for theAir-interface of the 4G Downlink Connection*

8th MCM, 6-8 July 2005, Antalya (jointly with 2nd Workshop)

For presentations please see the Section 5.2.2 2nd COST289 Workshop.

9th MCM, 3-4 November 2005, Madrid

- Á. Á. Vázquez, *Ultrawideband Communications* (invited)
- V. L. Balakirsky and H. Vinck, *Information Coding Schemes for Data Transmission Over Bus Systems*
- V. Bota, *LDPC vs. Convolutional Codes in Adaptive QAM Modulations on Mobile Radio Channels*
- D. Vukobratovic, *Optimality Considerations for Short-length LDPC Codes Construction*
- A. Wittneben, *Coherent Multiuser Relaying with Partial Relay Cooperation*
- I. Hammerstroem, *Power Allocations for Nonregenerative MIMO-OFDM Relay Links*
- E. Auger, B. Rankov, M. Kuhn and A. Wittneben, *Time Domain Precoding for MIMO-OFDM Systems*
- D. Yacoub et al., *Capacity of Measured MIMO Channels in Dependence of Array Element Spacing and Distance between Antennas*
- H. Sarı, *Frequency-Domain Techniques in Wireless Communications: OFDM, Precoded OFDM and SCT/FDE*
- S. Plass, *Spreading Codes for Radio Resource Management in MC-CDMA*
- A. Gameiro, *Scheduling, Multiuser Diversity and QoS*
- W. Teich, P. Kim and J. Lindner, *Bandwidth and Power Efficient Digital Transmission using Sets of Orthogonal Spreading Codes*
- L. Gutierrez, J. L. Pijoan, M. Deumal and F. Balder, *Adaptive procedure combining adaptive user grouping and bit loading in a GO-MC-CDMA*

10th MCM, 23-24 March 2006, Novi Sad

- M. Lutovac, D. Tosic, *Symbolic Analysis and Design of Communication Systems Using Computer Algebra Systems* (tutorial)
- V. Crnojević-Bengin, *Metamaterials - Concept and Applications* (invited)
- K. Baumgartner, *Architecture of a Scalable Wireless Sensor Network for Pollution Monitoring*
- F. Chiti et al., *Efficient MAC Protocols Design for Wireless Sensor Networks*
- S. Berger, *Optimal Power Loading for Orthogonal Multiuser Relaying*

- K. Hamdi, *Multiple-access Capability of MQAM-OFDMA Random Access Channel*
- V. Bota, Z. Plogar and M. Varga, *Performances of Convolutionally-Coded QAM Mapping Non-Coded Bits*
- M. Deumal Herraiz, *Peak Reduction of Multi-Carrier Ssystems by Controlled Spectral Outgrowth*
- R. Visoz, A. O. Berthet and S. Chtourou, *Frequency Domain Block Turbo-Equalization for Single-Carrier Transmission over MIMO broadband Wireless Channel*
- J. Bastos and A. Gameiro, *Performance of Equalization Schemes for Extended Alamouti Codes in MC-CDMA systems*
- J. A. R Cantero and M. J. F. Garcia, *A MIMO-OFDM system with backward compatibility with IEEE 802.16*
- S. Plass, *Increasing Transmit Diversity at the Cell Border with Smart Antennas*
- E. Aktas, *Distributed Base Station Processing in the Uplink of Cellular Networks*
- D. Radovic, *Overview of Power Line Broadband Technology*

11th MCM, 12-14 July 2006, Aveiro (jointly with 3rd Workshop)

- M. Safak, *Digital Video Broadcasting (DVB)*

  This seminar provided an overview of the recent developments on digital video broadcasting (DVB) and its implications on mobile communications, including DVB-T to fixed, portable and mobile devices, DVB-S2, DVB-H, interactive-capability in receivers, data broadcasting over IP-based networks, hybrid networks and multimedia home platform (MHP) to run software applications on all sorts of terminal devices. The main conclusion was that the trends are such that mobile communications, digital broadcasting and Internet are converging.

For other presentations please see the Section 5.2.3 3rd COST289 Workshop.

12th MCM, 30-31 October 2006, Florence

- J. L. Pijoan Vidal, *On OFDM Systems with Low Sensitivity to Nonlinear Amplification* (tutorial)
- R. Verdone, *COST 2100 - Pervasive Mobile and Ambient Wireless Communications* (invited talk)
- D. Tarchi, *IEEE 802.16 Based Mesh Networks: The WOMEN project*
- F. Chiti, A. Garcia Armada and A. Gameiro, *Integrating Research and Practice in Wireless Sensor Networks: The Experience of European Network of Excellence CRUISE*
- T. Zasowski, F. Troesch and A. Wittneben, *Partial Channel State Information and Intersymbol Interference in Low Complexity UWB PPM Detection*
- S. Morosi, *Pulse Repetition and Cyclic Prefix Communication Techniques in UWB-Impulse Radio Systems*
- S. Morosi, *Higher Order Impulsive Signals for Short Range Communications*
- M. Wetz, *A Hybrid Modulation Scheme for Noncoherently Detected OFDM-MFSK*

- S. Plass, *Correlation Properties in Time-Varying Cyclic Delay Diversity (TV-CDD)*
- V. Bota, Z. Polgar and M. Varga, *Joint Modeling of the Rayleigh-Faded Mobile Radio Channel and User-Chunk Allocation*
- S. Berger and A. Wittneben, *Phase Synchronization in Distributed Wireless Networks*
- M. Dikmen and M. Safak, *Performance Evaluation of WiMax Systems*

13th MCM, 11-13 April 2007, Göteborg, Sweden (jointly with 4th Workshop)

- M. Safak, *Towards Cognitive Communications- A new COST Action proposal*

  This new COST Action proposal is an outcome of some of the research conducted in the framework of the COST Action 289. It is based on improved adaptivity and flexibility in heterogeneous networks via the exploitation of cognitivity and cross-layer designs and the use of advanced software defined radio (SDR) concepts.

For other presentations please the Section 5.2.4 4th COST289 Workshop.

5.5 Conferences and Workshops

5.5.1 1st COST289 Workshop

The 1st COST289 Workshop was organized in Budapest during 7-9 July 2004 jointly with the 5th MCM. The Workshop aimed to increase the spirit of cooperation between the young researchers from the COST nations; coordinate their research efforts under the guidance of the project coordinators; and to improve their background scientific level about the joint research projects.

The following tutorial seminars were given by the leading scientists in their area of research:

- **Dr. Hiroyuki Atarashi**, DoCoMo, *Broadband Packet Wireless Access and its Field Experiments.*
  DoCoMo is one of the institutions heavily involved in 4G systems and has a proposal for the specifications for the uplink and downlinks. Dr. Atarashi presented uplink and downlink design proposals for 4G systems and discussed their relative advantages.The DoCoMo proposes the use of CDMA with variable spreading in time and frequency domains for the uplink.

- **Prof. Lajos Hanzo**, University of Southampton, *Recital on Multicarrier Communications: Space-Time Coded Versus Adaptive OFDM/MC-CDMA.*
  MC-CDMA and OFDMA are strong contenders for the 4G systems. Prof. Hanzo discussed in detail the relative advantages of these systems.

- **Prof. Armin Wittneben**, ETH Zurich, *Challenges in Pervasive Wireless Access*
  Prof. Wittneben gave an overview on the potential areas of applications, the state-of-art and trends in pervasive access systems.

- **Prof. Joan Lluis Pijoan**, Ramon Llull University, *Software Radio: An Enabling Technology for Mobile Communications.*
  Prof. Pijoan presented a review of research activities about SDR and discussed the potential areas of cooperation between the research teams.

The following presentations were given during the 1st Workshop:

Multicarrier Systems

- S. Plass, A. Dammann and S. Kaiser, *On Modeling and Analysis of a Coded OFDMA Downlink in a Multi-cell Environment*
- V. Bota, Z. Polgari, and M. Varga, *Performances of the LDPC-Coded Adaptive Modulation Schemes in Multi-Carrier Transmissions*
- G. Jeney, *Bit Loading Algorithms for Adaptive OFDM Wireless Systems*
- V. P. Gil Jiménez and A. Garcia Armada, *Bit-Loaded H-OFDM Performance in WPAN Environments*

Software Radio and Next Generation PHY

- X. Revés and A. Gelonch, *A Platform Abstraction Layer (P-HAL) for Software Radio Equipment*
- P. Bergada and C. Vilella, *SODIO: A Software Radio Platform for Advanced HF Communications*
- A. Zalonis, Ioannis Dagres and Andreas Polydoros, *Attributes of Real Time Intelligence in Flexible Radios*
- D. Tarchi**,** *Cross-layer Design for Multiple Access Techniques in Wireless Communications*
- F. Chiti, *Cross-layer Protocols Design for Next Generation Wireless Systems*

Receiver and Equalization

- J. Čížová, *Performance of the Microstatistic Multi-user Receiver in the Base-Band DS-CDMA Transmission System*
- S. Chtorou, R. Visoz and A. O. Berthet, *Whitened Matched Filter versus Channel Shortening for ST-BICM over MIMO ISI Channel*
- M. A. Dangl, Christian Sgraja and Jürgen Lindner, *Turbo Equalization for ISI Channels Incorporating Estimation Error Statistics*
- Z. Nemeth and S. Imre, *Interference Cancellation in MIMO Systems*

Spatial Systems

- G. Pay and M. Safak**,** *Array Relay*
- I. Hammerström and A. Wittneben, *Impact of Relay Gain Allocation on the Performance of Cooperative Diversity Networks*
- B. Rankov and A. Wittneben, *Distributed Spatial Multiplexing in Wireless Networks*

Software Demonstration

- V. Bota, M. Varga and Z. Polgar, *Simulation Programs for the Evaluation of the LDPC-Coded Multicarrier Transmissions*

The copies of the presentations are available in the Action web site and the attached CD.

5.5.2 2nd COST289 Workshop

The 2nd COST289 Workshop *Special Topics on 4G Systems* was organized in Antalya during 6-7 July 2005 jointly with the 8th MCM. Invited lectures by leading scientists provided the participants with the latest information and knowledge about technical and system aspects of spectrum and power-efficient-broadband communications.
The following invited lectures were given during the 2nd COST 289 Workshop:

- **Prof. Armin Wittneben, S. Berger, I. Hammerstroem and B. Rankov,** ETH Zurich, *Recent Theoretical and Experimental Results in Multiuser Zero Forcing Relaying*
  Prof. Wittneben presented recent results they obtained in the domain of the project on Pervasive Wireless Access for 4G.

- **Prof. Mikael Sternad**, Uppsala University, *The WINNER Beyond 3G Air-Interface Concept*
  Prof. Sternad gave a very informative presentation on the results that they obtained concerning the project on Wide Area Coverage and High Mobility Access Systems for 4G.

- **Prof. Andreas Polydoros**, University of Athens, *Radio Flexibility at the PHY Layer*
  This presentation was related to the project on the recent advances in the area of SDR.

- **Prof. Hermann Rohling**, Technical University Hamburg-Harburg, *OFDM Systems and Related Multiple-Access Schemes*
  Prof. Rohling gave an excellent presentation on the potential of OFDM as a transmission and multiple-access technique for the next generation systems in comparison with the other candidates.

These lectures were followed by the presentations given by the researchers, thus creating an environment of discussion and cross-fertilization among the participants. The following presentations were given during the 2nd Workshop:

Pervasive Access for 4G Systems (Session Chair: Prof. Armin Wittneben)

- A. Wittneben, S. Berger, I. Hammerstroem and B. Rankov, *Recent Theoretical and Experimental Results in Multiuser Zero Forcing Relaying*
- J. Zhao, A. Wittneben, *Cellular Relaying Networks: State of the Art and Open Issues*
- I. Hammerström, J. Zhao, A. Wittneben, *Temporal Fairness Enhanced Scheduling for Cooperative Relaying Networks in Low Mobility Fading Environments*
- S. Berger, A. Wittneben, *Cooperative Distributed Multiuser MMSE Relaying in Wireless Ad-Hoc Networks*
- R. Fantacci, D. Tarchi and G. Izzo, *A MAC Protocol for High-speed Multimedia WPANs*

Adaptive Modulation and Coding (Session Chair: Prof. Dr. Han Vinck, University of Essen)

- A.J.H.Vinck, *Coding for a Terrible Channel*
- Z. Polgar, F. Ardelean, M. Varga, V. Bota, *Performance Comparison of LDPC Codes Generated with Various Code-Construction Methods*
- A. Zsiros, A. Fülöp, G. Jeney, *Extending UTRAN Physical Layer with Coded Modulation Schemes*
- A. Mengi, G. Bauch, A.J.H. Vinck, *Space-Time Differentially Coded Orthogonal Matrix Modulation using QAM*

Channel Estimation and Equalization *(*Session Chair: Prof. Dr. Andreas Polydoros, University of Athens)

- A. Polydoros, *Radio Flexibility at the PHY Layer*
- M.A. Dangl, J. Lindner, *Turbo Equalization with Parametric Uncertainties: Comparison of SNR Estimation Algorithms*
- H. Senol, H.A. Cırpan, E. Panayırcı, M. Cevik, *KL-Expansion Based Channel Estimator for Space-time/frequency Coded OFDM Systems with Transmitter Diversity*
- S. Sand, R. Raulefs, A.Dammann, *Iterative Channel Estimation for MIMO MC-CDMA*
- V. Poulkov, G. Iliev, *Channel Equalization for OFDM*

OFDM Systems *(Session Chair: Prof. Dr. H. Rohling, Technical University of Hamburg-Harburg)*

- H. Rohling, *OFDM Systems and Related Multiple Access Schemes*
- S. Sezginer, H. Sari, *An Overview of Symbol Predistortion Techniques for PAPR Reduction in OFDM and OFDMA Systems*
- M. Deumal, I. Gutierrez and J. L. Pijoan, *PAPR Reduction in Orthogonal MC and MC-SS Systems*
- V. Jimenez, A.G. Armada, *Reducing the Feedback Information in OFDM-Based Adaptive Modulation Systems for 4G*
- C. Toker, S. Lambotharan, *Sensitivity of the Orthogonalization Methods for QO-STBC to Feedback Errors in an OFDM Environment*

4G Systems *(Session Chair: Mikael Sternad, Uppsala University)*

- M. Sternad, *The WINNER Beyond 3G Radio Interface Concept*
- M. Varga, V. Bota, and Z. Polgar, *User-Bin Allocation Methods for Adaptive-OFDM Downlinks of Mobile Transmissions*
- D. Radovic, *Effects of Channel on Multiuser CFO Estimation for Interleave OFDMA Uplink*
- M. E. Celebi, S. Sahin, U. Aygolu, *Space-time Block Code Selection for More Than Two Transmit Antennas*
- K. A. Hamdi, *On the Multiple-access Capability of a Shared Rayleigh Wireless Channel*
- D. Kocur, J. Čížová, S.Marchevský, *Sub-optimum MSF-MUD for CDMA Systems*

The copies of the presentations are available in the Action web site and the attached CD.

5.5.3 3rd COST289 Workshop

The 3rd COST289 Workshop *Enabling Technologies for B3G Systems* was organized in Aveiro, Portugal during 12-13 July 2006 jointly with the 11th MCM. The 17 technical contributions and presentations were discussed during the two-days 3rd COST 289 Workshop. Three of these presentations were invited talks given by

- **Prof. Ramjee Prasad,** Aalborg University, Denmark, *System and Service Aspects of Personal Networks Beyond 3G*
- **Dr. Jorge Fereira,** EU, Belgium, *Challenges in Heterogeneous Wireless Networks: Networking Everyone and Everything - The Shock of Two Cultures*
- **Prof. Hikmet Sari,** SUPELEC, France, *Multiple Access Techniques for the Uplink in Future Wireless Communication Systems* (co-authored by Cristina Ciochina and David Mottier)

The following presentations were given during the 3rd Workshop:

Short Range Systems and Techniques (Session Chair: Prof. Dr. Ramjee Prasad, Aalborg University, Denmark)

- R. Prasad, S*ystem and Service Aspects of Personal Networks Beyond 3G* (invited)
- F. Chiti, R. Fantacci, D. Marabissi and L. Innocenti, *Performance Analysis of a Novel Punctured Turbo Coding Scheme Suitable for TH-UWB Systems*
- Z. Nikolova, V. Poulkov, G. Iliev, G. Stoyanov, *Narrowband Interference Cancellation in Multiband OFDM Systems*

Future Wireless Systems (Session Chair: Dr. Jorge Pereira, CEC, Belgium)

- J. Pereira, *Challenges in Heterogeneous Wireless Networks: Networking Everyone and Everything - The Shock of Two Cultures* (invited)
- P. Marques, *Opportunistic Use of UMTS TDD Spectrum*
- J. A. Rivas Cantero, M. J. Fernandez-Getino Garcia, *Performance of Frequency Offset Synchronization in a Single and Multi-antena IEEE 802.16-2004 System*

OFDM (Session Chair: Prof. Dr. Arne Svensson, Chalmers University of Technology, Sweden)

- M. Wetz, W. G. Teich, J. Lindner, *PAPR Reduction Methods for Incoherent OFDM-MFSK*
- E. Auger, C. Mutti, M. Kuhn, A. Wittneben, *Interference Cancellation in MIMO-OFDM Systems with Outdated Channel State Information*
- S. Sand, C. Mensing, A. Dammann, *Transfer Chart Analysis of Iterative OFDM Receivers with Data Aided Channel Estimation*

Multiple Access (Session Chair: Prof. Dr. H. Sari, SUPELEC, France)

- C. Ciochina, D. Mottier, H. Sari, *Multiple Access Techniques for the Uplink in Future Wireless Communication Systems* (invited)
- K. Hamdi, *On the Channel Spacing of Random Access Wideband Channels*
- G. Psaltopoulos, F. Troesch, A. Wittneben, *On Achievable Rates of MIMO Systems with Nonlinear Receivers*

Acquisition, Equalization (Session Chair: M. Julia Fernandez-Getino, University Carlos III, Madrid, Spain)

- I. Perisa, J. Lindner, *Using Frequency-Offset Estimation Schemes for Acquisition*
- C. Toker, S. Altinis, *Robust Channel Shortening Equaliser Design*

Coding (Session Chair: Prof. Dr. Vasile Bota, Technical University of Cluj-Napoca, Romania)

- V. Bota, Z. Polgar, M. Varga, *Performance Evaluation of H-ARQ Adaptive Coded QAM Transmissions over Multipath Mobile Channels*
- Z. Polgar, V. Bota, M. Varga, *Performance of LDPC-Error Detecting Concatenated Codes Used in Adaptive OFDM Transmissions*
- D. Vukobratovic, V. Senk, D. Bajic, *On the Overhead Factors of Optimized LDGM-Staircase and LDGM-Triangle FEC Codes*

The copies of the presentations are available in the Action web site and the attached CD.

5.5.4 4th COST289 Workshop

The 4th COST289 Workshop *Contributions to Spectrum and Power Efficient Broadband Communications* was organized in Gothenburg, Sweden during 11-12 April 2007 jointly with the 13th and last MCM. The following four very interesting invited presentations were given on different aspects of wireless communications:

- **Prof. Anna Brunstrom**, Karlstad University, Sweden, *Reliable data transport in wireless networks*
- **Dr. Henrik Sahlin**, Ericsson AB, Mölndal, Sweden, *Mobile Broadband Technologies, where are we and where are we going?*
- **Prof. Bernard H. Fleury**, Aalborg University, Denmark, *Recent advances in radio channel characterization – The contribution from the NoE NEWCOM*
- **Dr. Fredrik Florén**, TeliaSonera AB, Malmö, Sweden, *Views on future wireless access from a Nordic and Baltic perspective*

Including the four invited lectures, the following 21 presentations made by various research teams of the COST 289 Action during the 4th Workshop:

Session 1

- A. Brunstrom, *Reliable Data Transport in Wireless Networks* (invited)
- G. Manes, R. Fantacci, F. Chiti, M. Ciabatti, G. Collodi, D. Di Palma, I. Nelli, and A. Manes, *D-STAR MAC Protocol: A Cross Layer Solution for Wireless Sensor Networks Endowed with Directive Antennas*
- L. Reggiani, M. Rydström, E. G. Ström and A. Svensson, *Adapting the Ranging Algorithm to the Positioning Technique in UWB Sensor Networks*
- M. Ovtcharov, G. Iliev, and V. Poulkov, *Narrowband Interference Mitigation in UWB systems*

Session 2

- H. Sahlin, *Mobile Broadband Technologies: Where Are We and Where Are We Going?* (invited)
- D. Marabissi, D. Tarchi, F. Genovese, and R. Fantacci, *A Finite State Modeling for Adaptive Modulation in Wireless OFDMA Systems*
- S. Sand, C. Mensing, C. Mutti, and A. Wittneben, *Adaptive Bit Loading and Transmit Diversity for Iterative OFDM Receivers*
- V. Bota, Z. A. Polgar, and M. Varga, *Performances of the H-ARQ Adaptive-QAM Transmissions over Multipath Mobile Channels*
- V. P. Gil Jiménez, T. Eriksson, A. García Armada, M. J. Fernández-Getino García, T. Ottosson, and A. Svensson, *Methods for Compression of Feedback in Adaptive Multi-carrier 4G Schemes*
- E. Alsusa and C. Masouros, *Adaptive Code Allocation for Interference Exploitation on the Downlink of MC-CDMA Systems*
- C. Ribeiro, M. J. Fernández-Getino García, V. P. Gil Jiménez, A. Gameiro, and A. García Armada, *Uplink Channel Estimation for Multi-user OFDM-Based Systems*

Session 3

- B. Fleury, *Recent Advances in Radio Channel Characterization – The Ccontribution from the NoE NEWCOM* (invited)
- M. Stemick and H. Rohling, *Effect of Carrier Frequency Offset on Channel Capacity in Mult-user OFDM-FDMA Systems*
- M. Karaman Colakoğlu and M. Şafak, *On the MIMO Channel Capacity Predicted by Kronecker and Müller Models*
- S. Plass, S. Sand, M. Sternad, and A. Svensson, *High Spectral Efficient and Flexible Next Generation Mobile Communications*
- M. Wetz, I. Periša, W. G. Teich, and J. Lindner, *Robust Transmission over Fast Fading Channels on the Basis of OFDM-MFSK*
- J. Krajňák, M. Deumal, P. Pavelka, D. Kocur, J.L. Pijoan, and P. Galajda, *Multi-user Detection of Nonlinearly Distorted MC-CDMA Symbols by Microstatistic Filtering*

Session 4

- F. Florén, *Views on Future Wireless Access from a Nordic and Baltic Perspective* (invited)
- S. Plass, G. Richter, and A.J. Han Vinck, *Coding Schemes for Crisscross Error Patterns*
- M. Deumal, A. Behravan, T. Eriksson, and J. L. Pijoan, *Evaluation of Performance Improvement Capabilities of PAPR-Reducing Methods*
- Z. A. Polgar, V. Bota, M. Varga, A. Gameiro, *Joint Modeling of the Multipath Rradio Channel and User-Access Method*

The copies of the presentations are available in the Action web site and the attached CD.

5.3 Tutorial/Review papers:

The list of tutorial/review papers is presented in chronolohical order:

5.3.1 5th MCM and 1st COST 289 Workshop in Budapest, 7-9 July 2004:

Hiroyuki Atarashi, DoCoMo, *Broadband Packet Wireless Access and Its Field Experiments.*

Lajos Hanzo, University of Southampton, *Recital on Multicarrier Communications: Space-Time Coded Versus Adaptive OFDM/MC-CDMA.*

Armin Wittneben, ETH Zurich, *Challenges in Pervasive Wireless Access*

Joan Lluis Pijoan, Ramon Llull University, *Software Radio: An Enabling Technology for Mobile Communications.*

5.3.2 6th MCM in Barcelona, 28-29 October 2004:

Simone Morosi, University of Florence, *Reconfigurable Antennas for Future Wireless Communications* (Tutorial provided in the framework of NEXWAY, European Network of Excellence)

5.3.3 7th MCM in Oberpfaffenhofen, Munich,7-8 March 2005:

Stefan Kaiser, DLR, *Overview on MC-CDMA*

5.3.4 8th MCM, Antalya, 6-8 July 2005:

A. Wittneben, ETH Zurich, *Recent Theoretical and Experimental Results in Multiuser Zero Forcing Relaying*

A. Polydoros, Technical University of Athens, *Radio flexibility at the PHY layer*

H. Rohling, Technical University of Hamburg-Harburg, *OFDM Systems and Related Multiple Access Schemes*

M. Sternad, Uppsala University, *The WINNER Beyond 3G Radio Interface Concept*

5.3.5 9th MCM, 3-4 November 2005 Madrid:

Álvaro Álvarez Vázquez, ACORDE, *Ultrawideband Communications: state-of-the-art and research issues.*

The tutorial was considered to be very useful and attracted a lot of interest among the participants. It provided useful information about this new and interesting area of research, which could not be covered by the Action because of the lack of sufficient number of scientists who are interested in this area.

5.3.6 10th MCM, 23-24 March 2006, Novi Sad:

Prof. Dr. Miroslav Lutovac, Prof. Dr. Dejan Tosic, University of Belgrade, *Software for algebraic-symbolic and numerical processing in communication systems*
The tutorial emphasized the advantages of symbolic processing in the analysis of telecommunication systems. The authors demonstrated the usefulness of their approach by some examples in various fields of electrical and electronics engineering.

Dr. Vesna Crnojević-Bengin, University of Novi Sad, *Metamaterials - Concept and Applications*
This very interesting tutorial clearly showed the great potential that the use of metamaterials have in telecommunication systems.

5.3.7 11th MCM, 12-14 July 2006 Aveiro:

Prof. Ramjee Prasad, Aalborg University, Denmark, *System and Service Aspects of Personal Networks Beyond 3G*

Dr. Jorge Fereira, EU, Belgium, *Challenges in Heterogeneous Wireless Networks: Networking Everyone and Everything - The Shock of Two Cultures*

Prof. H. Sari, SUPELEC, France, *Multiple Access Techniques for the Uplink in Future Wireless Communication Systems* (co-authored by Cristina Ciochina and David Mottier)

Prof. Mehmet Şafak, Hacettepe University, Turkey, *Digital Video Broadcasting- An Overview*

5.3.8 12th MCM, 30-31 October 2006 Florence:

Prof. Joan Lluis Pijoan, Ramonn Lull University, Barcelona, Spain; *On OFDM Systems with low Sensitivity to Nonlinear Amplification (tutorial)*

Prof. Roberto Verdone, University of Bologna, Italy; *COST2100 - Pervasive Mobile and Ambient Wireless Communications;* An invited talk on the new COST Action 2100.

5.3.9 13th MCM, 11-13 April 2007 Göteborg:

Prof. Anna Brunstrom, Karlstad University, Sweden; *Reliable Data Transport in Wireless Networks*

Dr. Henrik Sahlin, Ericsson AB, Mölndal, Sweden; *Mobile Broadband Technologies; Where Are We and Where Are We Going?*

Prof. Bernard H. Fleury, Aalborg University, Denmark; *Recent Advances in Radio Channel Characterization – The Contribution from the NoE NEWCOM*

Dr. Fredrik Florén, TeliaSonera AB, Malmö, Sweden; *Views on Future Wireless Access from a Nordic and Baltic Perspective*

Prof. Mehmet Safak, Hacettepe University, Turkey, *Towards Cognitive Communication- A COST Action Proposal.*

5.4 Publications

The detailed list of publications is presented in Annex B and they are also posted in the web site of the Action: http://cost289.ee.hacettepe.edu.tr

5.5 Web site

The web site is used to present the activities of the Action. The web site address is http://cost289.ee.hacettepe.edu.tr. The site is divided into two sections: an open section and a section restricted to the participants of the Action only. In the open section the following information is available: Status, MoU, Progress Reports, Chair, Participating Organisations, Meetings, Signatories and Related Links. The part accessible only through password is the List of Publications, which contains the working documents of the WGs and some electronic copies of the presentations.

5.6 Scientific and Technical Co-operation

Close scientific and technical cooperation is desired with other relevant COST Actions, scientific institutions, and research programmes, especially in the EU framework programmes.

- During 6th MCM in Barcelona, 28-29 October 2004, the following lecture was offered by the NoE NEXWAY:

  Prof.Simone Morosi, University of Florence, *Reconfigurable Antennas for Future Wireless Communications* (Tutorial provided in the framework of NEXWAY, European Network of Excellence)

- The following lectures, were presented during the 2nd COST 289 Workshop, 6-7 July 2005, Antalya, by Prof. Mikael Sternad, from European NoE WINNER. and by Dr. P. Fazekas from the NoE NEWCOM.

  Prof. Mikael Sternad, Uppsala University; *The WINNER Beyond 3G air-Interface: A First Outline*, 2nd COST 289 Workshop, 6-7 July 2005, Antalya, Turkey.

  Dr. Peter Fazekas, Budapest University of Technology and Economics, *NoE in Wireless COMmunications (NEWCOM); structure, aim and achievements*, 2nd COST 289 Workshop, 6-7 July 2005, Antalya, Turkey.

  This presentation created an opportunity to discuss the relative advantages of NoE's and COST Actions. The discussions led to a common understanding that combining the financial flexibility of NoE's and the administrative flexibility of COST Actions could lead to an optimuml solution.

- The following lectures were given by eminent scientists, who are not a member of the Action, during the 1st Workshop in Budapest, 7-9 July 2004.

  Dr. Hiroyuki Atarashi, DoCoMo, *Broadband Packet Wireless Access and Its Field Experiments.*

  Prof. Lajos Hanzo, University of Southampton, *Recital on Multicarrier Communications: Space-Time Coded Versus Adaptive OFDM/MC-CDMA.*

- Dr. Jorge Ferrira from EU gave the following presentation during the 11th MCM, 12-14 July 2006, Aveiro, Portugal:

  Dr. Jorge Fereira from EU, Belgium, *Challenges in Heterogeneous Wireless Networks: Networking Everyone and Everything - The Shock of Two Cultures*

- The following presentations were given during the 12th MCM on COST Action 2100, the WOMEN project and the NoE CRUISE:

  Prof. Roberto Verdone from University of Bologna, Italy, *COST2100 - Pervasive Mobile and Ambient Wireless Communications*

  Dr. Daniele Tarchi from University of Florence, Italy, *IEEEE 802.16 based mesh networks: The WOMEN project*

  Dr. Francesco Chiti, University of Florence, Italy, **Prof. Ana Garcia Armada,** University of Carlos III of Madrid, Spain, and **Prof. Atilio Gameiro,** University of Aveiro, Portugal, *Integrating Research and Practice in Wireless Sensor Networks: The Experience of European Network of Excellence CRUISE*

- A presentation resulting from the cooperation with NoE NEWCOM were given during 13th MCM and 4th Workshop, 11-13 April 2007, Gothenburg, Sweden:

  Prof. Bernard H. Fleury, Aalborg University, Denmark, *Recent advances in radio channel characterization – The contribution from the NoE NEWCOM.*

5.7 Transfer of Results

The transfer of the research results is considered to be a key issue and a number of target groups have been identified, e.g., technology developers and providers, scientists, industry representatives and standardisation bodies as the key recipients of information. The actual dissemination is implemented based on the Action web site. Other means will include

- Electronic media in which the research results is/will be entered in the Internet for easy retrieval by researchers and other professionals.
- Specific contacts with already established agencies, initiatives and programmes.
- Traditional means such as reports, academic journals, conferences, seminars and workshops.

5.7.1 Special Issue of Springer Journal Wireless Personal Communications:

Among the 17 presentations during the Final Workshop, held in Göteborg, 11-12 April 2007, based on the previous review results, 13 papers are selected by the editorial board, consisting of Prof. H. Rohling, Prof. A. Svensson, Prof. A. Wittneben and Prof. M. Safak. These papers, following a second review process, are submitted in June 2007 to the Springer Journal Wireless Personal Communications, with editor-in chief Prof. Ramjee Prasad, from University of Aalborg, Denmark, for publication in a special issue (SI). The SI is expected to be published in early 2008.

The list of papers accepted for publication in the SI is given below:

- M. Stemick and H. Rohling, *Effect of Carrier Frequency Offset on Channel Capacity in Multi-user OFDM-FDMA Systems*
- F. Chiti, M. Ciabatti, G. Collodi, D. Di Palma, R. Fantacci, G. Manes, A. Manes and I. Nelli, *D-STAR MAC Protocol: a Cros-layer Solution for Wireless Sensor Networks Endowed with Directive Antennas*
- M. Rydström, L. Reggiani, E. G. Ström and A. Svensson, *Adapting the Ranging Algorithm to the Positioning Technique in UWB Sensor Networks*
- S. Plass, G. Richter, and A. J. Han Vinck, *Coding Schemes for Crisscross Error Patterns*
- S. Sand, C. Mensing, C. Mutti and A. Wittneben, *Adaptive Bit Loading and Transmit Diversity for Iterative OFDM Receivers*
- V. Bota, Z. A. Polgar, M. Varga, *Performances of the H-ARQ Adaptive-QAM Transmissions over Multipath Channels*
- S. Plass, S. Sand, M. Sternad, and A. Svensson, *High Spectral Efficient and Flexible Next Generation Mobile Communications*
- M. Karaman Colakoglu and M. Safak, *On the MIMO Channel Capacity Predicted by Kronecker and Müller Models*
- V. P. G. Jiménez, T. Eriksson, A. García Armada, M. J. Fernández-Getino García, T. Ottosson, and A. Svensson, *Methods for Compression of Feedback in Adaptive Multi-carrier 4G Schemes*
- M. Wetz, I. Periša, W. G. Teich and J. Lindner, *Robust Transmission over Fast Fading Channels on the Basis of OFDM-MFSK*
- C. Ribeiro, M. J. Fernández-Getino García, V. P. Gil Jiménez, A. Gameiro, and A. García Armada, *Uplink Channel Estimation for Multi-user OFDM-based Systems*
- M. Deumal, J. L. Pijoan, A. Behravan and T. Eriksson, *Evaluation of Performance Improvement Capabilities of PAPR-reducing Methods*

- J. Krajňák, P. Pavelka, D. Kocur, P. Galajda, M. Deumal, J.L. Pijoan, *Multi-user Detection of Nonlinearly Distorted MC-CDMA Symbols by Microstatistic filtering*

6 ECONOMIC DIMENSION

30 institutions from 19 signatory countries participated the Action, with, on the average, 2 representatives per country. The evolution of the number of the signatories and the annual COST budget (actually spent) is listed below:

The list of the annual COST-ESF budget:

Period March -June 30 2003:	6 signatories	Inaugural MCM
Period 2003-2004:	16 signatories	39 715 Euro
Period 2004-2005:	18+1 signatories	58 735 Euro
Period 2005-2006 :	19 signatories	76 922 Euro
Period 200-April 2007 :	19 signatories	95 794 Euro
Total COST-ESF budget:		*271 166 Euro*

As also suggested in the MoU, the economic value of the research conducted by each country per year can be estimated from the following

½ engineer/researcher/secretary	50 000 Euros
½ technician	30 000 Euros
2 Ph.D. students	70 000 Euros
Equipment and material costs	30 000 Euros
Travel	20 000 Euros
Total per signatory per year	**200 000 Euros**

The total cost per signatory will be about 200 000 Euros per year and 800 000 Euros in four years of duration of the Action. The total economic dimension over four years for 19 nations is predicted to be approximately 15.2 Million Euros.

During the four years of existence of this Action, thirteen MCMs and four Workshops were organised. This is believed to be typical for a COST Action. Below is given the statistics of attendance and reimbursement by COST-ESF:

MCM number	No. of participants	No. of reimbursed participants	Amount reimbursed (Euro)
Inaugural MCM, 24 March 2003, Brussels	12	Reimbursed by COST	?
2nd MCM, 3-4 July 2003, Hamburg	16	10	12026,00
3rd MCM, 30-31 October 2003, Kosice	25	13	12420,00
4th MCM, 15-16 March 2004, Zurich	30	20	12529,16
5th MCM, 7-9 July 2004, Budapest	40	23	17272,37
6th MCM, 28-29 October 2005, Barcelona	30	14	9802,20
7th MCM, 7-8 March 2005, Oberpfaffenhofen	35	23	14455,68
8th MCM, 6-8 July 2005, Antalya	46	31	31704,67
9th MCM, 3-4 November, Madrid	32	23	17373,11
10th MCM, 23-24 March 2006, Novi Sad	32	19	15200,13
11th MCM, 12-14 July 2006, Aveiro	34	21	20 887,99
12th MCM, 30-31 October 2006, Florence	29	23	17 900,38
13th MCM, 11-13 April 2007, Gothenburg	40	34	30 094,23
Total	**401**	**254**	**211 667**
Average per MCM	**401/13=31**	**254/12=21**	**17 639**
Average per reimbursed participant			**840**

We occasionaly encountered some difficulties in financial matters, e.g., in the transfer of allocated budget to our account and/or the need to increase the budget due to the insufficiency of the initially allocated budget. Because of potential shortage of budget, we developed a policy such that the host institutions covered costs of Workshops at least partially, whenever possible. In some years, the increased budget could not be

fully used because of the following reasons: Our understanding about the reimbursement policy for the COST MCMs was such that at most two scientists from each COST nation could be reimbursed per MCM. In view of the average amount of reimbursement of 840 Euros per participant and the average number of reimbursed participant of 21 per MCM, it was practically impossible to spend the increased budget.

The Action management could have great flexibility and devise a fairer reimbursement policy if this restriction could have been relaxed, e.g., Germany has four productive and actively participating institutions and the expenses of their participants can not all be reimbursed.

Based on the above financial figures one can draw the following conclusions:

- Total economic dimension of the Action: 15.2 Million Euros
- Total COST-ESF budget (spent): 271 166 Euros (1.8 % of 15.2 Million Euros)
    - COST-ESF budget used for reimbursement of travel expenses: 211 667 Euros (78 % of 271 166 Euros)
    - COST-ESF budget for STSMs, Annual Review Meetings, Workshops, secretarial assistance etc.: 59 499 Euros (22 % of 271 166 Euros)

As can also be observed from the above table, the average amount of reimbursement for a participant is typically 840 Euro per MCM. Thus, in the light of the above, the COST Action 289 clearly proved to be a very cost-effective means of conducting a very successful research program in an international environment.

7 SELF EVALUATION

7.1 General Considerations

COST Actions are very useful platforms for establishing and conducting joint research activities between researchers from different research institutions. They are not structured as in NoEs and should not be expected to be so. The ad hoc structure of COST Actions is *innovative* and brings *richness* to the research program. However, this should not imply that COST Actions should not have any control/coordination mechanism for scientific research. Since the participants of a COST Action can not be forced to commit themselves to a pre-structured scientific program with some strict deadlines, its success is believed to be critically dependent on its management.

Successful management of a COST Action first of all requires an atmosphere of cooperation between the participants. This can be achieved by creating a good social and scientific atmosphere as well as a common interest between the participants. The common interest may be maximized by investing in an education/learning/training process especially in the early phase of the Action, by creating a synergy and a productive research environment and a faster and higher publishing opportunity. The COST environment can be very useful for training the young researchers by using the Training Schools, especially during the initial phase of the Action, and for initiating research cooperations via the STSMs. Similarly, tutorials, review and survey type presentations by invited speakers could be very attractive for the participants. For a productive research environment, one needs to identify novel research areas which are

in the area of interest of the majority of participants, and appoint a coordinator, willing to dedicate a considerable percentage of his time to this project. Establishing research cooperations between institutions having manpower on one side and research projects on the other side is believed to be very rewarding. Another very important point is to be able attract good scientists/engineers to the Action in a very competitive European environment, e.g. NoEs.

7.2 Evaluation of the COST Action 289

7.2.1 Achievements

Excluding the Inaugural MCM, the total budget which was spent during the four years period of this Action was 271 166 Euro. The amount constitute only 1.8 % of the total estimated economic dimension of 15.2 Million Euros for the Action. The remaining part of the budget is covered by the member states. Therefore, such a project acts as a very convenient vehicle for conducting joint research by the COST countries. Comparing the spent budget with the achievements made during this period, the financial support to this Action is obviously very cost-effective for the COST and the participants for whom it was very enriching and productive. Social benefits, vis-à-vis the European integration, gained through this Action are, in our opinion, at least as important as the technical benefits.

The success of this Action is closely related to the efficient use of the Short Term Scientific Mission (STSM) program designed to send young researchers for scientific visits to cooperating institutions. During the four-year period, the Action supported 14 young researchers to visit 7 different institutions to cooperate and conduct joint research. These visits were usually longer than one month, which shows the extent and effectiveness of cooperation. According to the decision taken by the Management Committee (MC), all of the visitors were Ph.D. students and the reimbursement of their expenses was made according to a set of rules imposed by the MC, within the framework of COST regulations. The researchers who have been in a STSM were asked to present a report about their scientific visits in a MCM. This approach for encouraging and educating the young researchers may be considered as a positive part of the Action. As a result of these STSMs, as indicated in the section 3.5.1 Publications Resulting from STSMs, until presently, four journal papers and a conference paper were (accepted to be) published. Some additional publications are anticipated in the near future. A few tens of M.Sc. and Ph.D. students either completed or are about to complete their studies in the framework of COST 289 and with the support by the STSM program.

During the four years, 13 MCMs were organised. Four of these MCMs were jointly organised with the Workshops. 401 attendants of 13 MCMs presented 152 presentations and 24 tutorial/review/survey papers. In addition, 85 journal papers, book chapters and books and 347 conference papers were published.

The papers presented during the 4th Workshop resulted mostly from the cooperation during the four years between different institutions participating to the COST Action 289. It was noted that 10 out of these 17 papers represent the result of joint research between different institutions. This number may be considered as a measure of cooperation between the Action members. 13 of these 17 papers were scheduled for

publication in a special issue of the Springer Journal Wireless Personal Communications in early 2008. The results of cooperation will be reflected in publications still to come.

COST Action 289 is believed to be very successful because of the following reasons:

- A very good environment of scientific cooperation was created between more than 100 researchers of 30 institutions from 19 COST countries. This resulted in scientific and social development of the participants.
- Significant contributions were provided to the litterature concerning the three projects on Wide Area Coverage for 4G, Pervasive Access for 4G and the SDR.
- A significant number of research papers were published either jointly between participating institutions or by the researchers belonging to various institutions.
- Young researchers were supported in their research and its return was very positive, i.e., joint research results were mainly due to their cooperation because of their mobility.
- The total amount of money spent is very modest compared to the benefits gained from the Action.
- The researchers of some countries, who do not have as strong research infrastructure as those of some others, were supported. This contributed to the scientific development of the research teams of these countries and their integration to Europe.
- The great majority of the participants were happy to be involved in this Action. Consequently, the very strong support to apply for another COST Action lead to a new COST Action proposal, entitled “Towards Cognitive Systems”.
- Some of the scientific results (13 papers) are scheduled for publication in Springer Journal “Wireless Personal Communications” in early 2008. This Journal has a high visibility in the telecommunications community.

7.2.2 Weaknesses

Some members, though they signed the MoU, did not have the opportunity to contribute much to the Action. For example, Belgium never attended the MCMs and Malta attended only once. Similarly, Polytechnic University of Catalunya, Budapest University of Technology and Economics, University of Athens, Aristotle University of Thessaloniki and NTNU from Norway could provide only limited contribution with very low attendance rates.

The Polytechnic University of Catalunya, Budapest University of Technology and Economics and University of Athens were the major institutions to be involved in the project on Software Defined Radio (SDR). However, due to their lack of participation, the participation to the *SDR project* was not at the same level as to the projects on *Wide Area Access* and *the Pervasive Access*. In our opinion, the main reason why these institutions could not contribute to the Action at a desired level is

the wide diversity of financial support mechanisms presently available for the scientific projects, including the NoEs, in the European arena and the heavy involvementof these institutions in some of these projects.

7.2.3 Proposals for Improvement of COST Actions

Based on the past experience, the following measures could be a reasonable approach for a successful COST Action:

- Identify, at the very early phase of the Action, a well-defined and detailed research program based on the MoU. The success of such a research program, which consists of the sum of well-defined Work Packages, could be related to some milestones.

- The acceptance of new members to the Action could be based on their committment to one of the clearly defined small Work Packages. However, this is in contrast with the current COST regulations according to which any nation can join the Action within the first six month of the Action without prior to MC approval. Nevertheless, this problem can be solved to a great extent by a good Action management. The choice and the effort of coordinators in charge of these Work Packages are critical in the success of the Action.

- Invited talks, frequent workshops, STSMs and training schools can be very convenient platforms for fostering the success of a COST Action. Invited lectures are helpful not only for the young researchers but also for widening the spectrum of the senior researchers. Invited lecturers from outside the Action could provide more diversity to the research program of the Action.

- Investment on young researchers is believed to be very much rewarding in a COST Action environment. If young researchers, in the initial phase of their Ph.D. program, can be trained by the mechanisms cited-above, they could carry out their research in an international environment and reach to the most productive phase of their research towards the end of the Action. Establishing and sustaining cooperations between young researcher were observed to be much easier because of the heavy time schedules of the senior researchers.

- Publication of the scientific results of these projects were observed to be very much stimulating for the researchers, since it may be easier and faster to publish in this environment. It is strongly suggested to publish the research results in scientific journals for example every two years. COST-ESF could even consider publishing some scientific journals for this purpose.

- Nevertheless, in view of the rapid developments in the area of information and communication technologies, the Actions should be adaptive in incorporating new and innovative research areas within the framework of the Action MoU.

ANNEX A

SCIENTIFIC RESULTS

The project on *Wide Area Coverage and high mobility access systems for fourth generation (4G)* addresses the problems of centralized systems with high mobility corresponding to lower data rates but wider coverage areas. The project on *Pervasive Wireless Access for 4G* is mainly concerned with decentralized networks with lower mobility, much higher data rates, and consequently restricted coverage areas. The *SDR* project aims to bridge these two projects horizontally since various systems should be implemented in the same platform for the reconfigurability and adaptivity purposes.

These projects were believed to be sufficiently flexible so that each researcher could choose his particular research topic and thus make the best use of his/her expertise. However, this did not prevent the individual research results to arrive to some valuable contributions and coherent solutions to the problems defined for the particular project.

During the 4 years of existence of the Action, 13 MCMs and 4 Workshops were organized. The research efforts resulted in 152 presentations and 24 tutorials. These 152 presentations, 85 journal papers, book chapters and books and 347 conference papers are available in the Action web site (http://cost289.ee.hacettepe.edu.tr). A Special Issue of the Springer Journal Wireless Personal Communications is dedicated to publish 13 selected research papers by COST 289 research teams. This special issue is scheduled for early 2008.

The above-cited publications originate from

a) joint research efforts between various research teams on the above-cited three projects,
b) individual research results based on one of the three projects, and
c) individual/joint research efforts of the participants not necessarily related to one the three projects cited-above;

In view of the large number of publications, following a brief description of each of the three projects, in this section we will provide short summaries of some of the selected publications related these projects, with special emphasis on the joint publications. The reader may refer to the Action web site (http://cost289.ee.hacettepe.edu.tr) and the CD for the details of these publications and the other related publications.

A.1. WIDE AREA COVERAGE AND HIGH MOBILITY ACCESS SYSTEMS FOR 4G

Network and service architectures of 3G networks are primarily static and have difficulty in meeting the ever-increasing requirements for high-throughput high-performance multimedia applications. Furthermore, 3G systems, consisting primarily of wide area networks (WANs), fall short of supporting heterogeneous networks. Future network infrastructures will be based on Internet protocol (IP) architecture

supporting heterogeneous wireless systems, ranging from 2G/3G/4G cellular radio, satellite-based networks, wireless local area networks (WLANs), worldwide interoperability for microwave access (WiMax) systems, sensor networks, and digital video and audio broadcasting (DVB, DAB). These systems will provide high data rates, convergence and interoperability of heterogeneous mobile and broadband network technologies, optimized traffic processing between core and access networks, dynamic handover, flexibility, adaptivity, security, multicasting, end to end connectivity, global roaming, scalability and multiple classes of service with variable end-to-end quality of service (QoS) requirements.

Intense research efforts are currently ongoing towards the definition of physical layer for 4G systems, which should provide services comparable to those offered by wired networks for a variety of applications such as interactive multimedia, voice over IP, network games, and video conferencing [1]. There are strong requirements for high data rates, high mobility, and flexible technologies. The traffic load of these systems will likely be dominated by the bursty data traffic.

There are many aspects of 4G systems, including detection techniques, antenna systems, adaptive modulation and coding, multiple access (MA), hybrid ARQ techniques, admission control, power control etc., to be studied in detail [2]. Since very high data rates are required, transmission system will very likely be based on multicarrier technology [3]. There is a close relationship between the choices of the appropriate *transmission* and *MA techniques*. MA implies the efficient sharing of the available bandwidth among a large number of users. The MA techniques currently used in 2G/3G, including those based on time division multiple access and direct sequence code division multiple access (DS-CDMA) and possible combinations of the two, are suitable for voice communications but not necessarily for the bursty data traffic [1].

Several proposals have already been made towards the definition of 4G systems; these are mostly based on orthogonal frequency division multiplexing (OFDM) and CDMA. A national project in Sweden has suggested an adaptive multiplexing and OFDM transmission system for the downlink [4],[5]. NTT DoCoMo has suggested a scheme based on the combination of OFDM and CDMA [6].

In the *downlink*, the signals are multiplexed within each cell, while it is multiple accesses between cells only. In the *uplink,* the situation is much more complicated since a combination of multiplexing and MA takes place in each terminal when more than one service is transmitted at the same time. The uplink is normally asynchronous and oscillators in different terminals are not synchronized. Special care must be given to use OFDMA in the uplinks due to its sensitivity to frequency synchronization errors. It may also be more difficult to use channel state information at the transmitter in the uplink, at least in FDD systems, due to the increased overhead. Currently, the intense research efforts are ongoing as to the relative advantages of various transmission, multiple access and duplexing techniques [7]-[13].

For the 4G system uplinks, the following DoCoMo proposal may be used as a reference:

- Available uplink bandwidth is 40 MHz
- Carrier frequency likely around 5 GHz
- Maximum speed is 250 km/h

Note that the data rate requirement for high mobility by ITU is 100 Mbps, and this should be achieved in a 40 MHz bandwidth.

The DoCoMo proposal for the downlink parameters is given by:

- Available downlink bandwidth is 100 MHz
- Carrier frequency likely around 5 GHz
- Maximum speed is 250 km/h

Further studies are needed for performance comparisons between OFDM- and CDMA-based systems for the downlink. A fair comparison between these systems in a multi-cellular environment with all the complexity taken into account is believed to be still missing.

All performance evaluations may be done using the widely accepted UMTS channel models. Preferably, performance should be evaluated in a multi-cell environment, but single cell performance and single link performance is acceptable as a starting point.

In this project, members of the Action focused their efforts to design and analyze physical layer solutions for 4G uplinks and downlinks. Here, the interest is in systems with wide area coverage and high mobility, and there is no restriction on the choice of transmission and MA techniques. So, in principle, any physical layer technique can be used and combined in such a way that high bandwidth- and power-efficient uplinks and downlinks are obtained.

Five young researchers were hosted by Chalmers University of Technology on STSM during 2004 to establish a common understanding and cooperation on the research undertaken. These efforts resulted in several presentations in the COST 289 Workshops and publications in the Special Issue of Wireless Personal Communications (see 3.5.1 Publications Resulting From STSMs).

The following can be cited amongst the research topics related to this project:

- Uplink and downlink designs for 4G
- Adaptive transmission technologies for 4G uplink and downlink design
- Channel prediction and feedback information in OFDM-based adaptive modulation systems for 4G..
- Investigation of multiplexing and diversity techniques in 4G-downlinks by using adaptive MIMO systems.
- Effects of channel on multiuser CFO estimation for interleaved OFDMA uplink
- User-resource allocation methods for adaptive OFDM downlinks for mobile transmissions
- Multiple access techniques in uplinks and downlinks
- OFDM and MIMO-OFDM systems
- Cross-layer designs
- Smart antennas
- Adaptive/reconfigurable systems

A.1.1. S. Plass, S. Sand, M. Sternad and A. Svensson, High spectral efficient and flexible next generation mobile communications [14]

Simon Plass from DLR, Germany, visited Chalmers University of Technology during 20.9.2004-24.9.2004 on STSM. As a result of this visit, this paper [14] was produced by the researchers from DLR, Chalmers University of Technology and the University of Uppsala.

The challenges, requirements, and possible new techniques for a next generation mobile communications system are investigated in this paper. The so-called 4G systems aim at throughput rates of more than 100 Mbit/s outdoor with high mobility and 1 Gbit/s indoor. This requires new advanced techniques in the air interface of such a system. New techniques are outlined and a future basic physical layer concept is introduced. A high spectral efficient and flexible air interface has to be designed to achieve the proposed demands of very high data rates. The flexibility of the air interface highly depends on the availability of the channel state information. With this information most of the processes on the physical layer can be optimized at the transmitter and receiver side. Thus, the future challenge is an efficient design of the adaptive process blocks such as the modulation, space-time-frequency precoding and scheduling, and corresponding reverse operations.

The adaptivity to the channel of all the modules in such a possible concept is highlighted. Since the needed large bandwidth for high data rates is a very valuable resource, future communications systems need high spectrum flexibility. An overview over possible spectrum flexibility concepts is also given and discussed in the paper. Two different mechanisms are identified, namely spectrum sharing and spectrum assignment.

Finally, the severe problem of emerging inter-cell interference can be overcome by new resource management mechanisms in the transmitter, e.g., adaptive varying frequency reuse or inter-cell interference mitigation. Theoretically, gains from using inter-cell interference avoidance schemes are large, but maximal gains would require fast and tight inter-cell coordination. Frequency partitioning in cellular networks on a slower time-scale has for a long period received interest, using power control, dynamic channel assignment, and channel borrowing. Note that the packet-switched channel-aware scheduled transmissions that will take place in 4G systems complicates the use of many of the previously suggested schemes for inter-cell interference avoidance. For example, it is not, without additional side information, possible to conclude that the interference power in a set of sub-carriers is likely to be higher/lower than average just because it is measured as high/low at present. This is a major challenge for dynamic measurement-based resource assignment schemes.

A.1.2. V. P. Gil Gimenez, T. Eriksson, A. G. Armada, M. J. Fernandez-Getino Garcia, T. Ottoson and A. Svensson, Methods for Compression of Feedback in Adaptive Multicarrier 4G Systems [15]

The cooperation between the University of Carlos III of Madrid and Chalmers University of Technology was established as a result of the STSM by **Victor Pedro Gil-Jimenez** from University Carlos III of Madrid to Chalmers University of Technology during 4.9.2004 - 9.12.2004. The paper [15] was presented in 4th

Workshop and also accepted for publication in the Special Issue is a good example of the usefulness of the STSMs.

Wireless channels, in particular for cellular systems, have a common characteristic; they are time varying. In order to exploit the variations and approach the Shannon capacity, systems are becoming adaptive attempting to adjust the transmission as much as possible to the instantaneous channel conditions. Furthermore, in a multi-user scenario, one can also use the so-called multi-user diversity, since the probability that at least one user experiences good channel propagation conditions increases as the number of users does. If there are many users, it is highly probable that not all of them will experience poor channel propagation but at least one of them will be in a good channel. Moreover, this situation is more advantageous in an OFDMA (Orthogonal Frequency Division Multiple Access) system, where the different orthogonal sub-carriers can be assigned to different users. The power and flexibility of an OFDM and OFDMA system are the reasons why OFDMA systems are one of the strong candidates being proposed for the downlink in the mobile 4G.

Regarding the adaptivity, in order to maximize the throughput, at the BS or central point there is a scheduler that decides which user (or users) will transmit and in which sub-carriers. The throughput-maximizing scheduling policy is to transmit to the user with the highest SNR. Since the channel and SNR are usually estimated at the receiver, they must be fed back to the transmitter. At the transmitter side, the scheduler selects which users are going to transmit and also the adequate MCS (Modulation and Coding Scheme) based on the fed back SNR by every user. The data rate needed to convey the feedback may be very high, especially in multi-user OFDM systems where terminals must send to the transmitter MCS in every sub-carrier. Moreover, it will depend on how often this information is expected. For this reason, the literature is increasing on how efficient the data feedback should be.

In this paper, the authors categorize the techniques for reducing the feedback into three groups, namely quantization, compression and SNR-limited. In the first group, the way to reduce the feedback rate is to quantize data (applied to real SNR values) and therefore the feedback is reduced. In the second group, some compression techniques are applied to feed back data such as LZW (Lempel-Ziv-Welch) lossless algorithm, Huffman codes or different ones where entropy compression is used with an UVLC (Universal Variable Length Code). And finally in the third group, for a maximizing-throughput scheduling, the BS only allows to feed back data to those terminals with good channel conditions (above some threshold), sometimes denoted opportunistic feedback. The amount of feedback reduction using these techniques can be very high and thus they should be used jointly with the quantization or compression. It has been shown that opportunistic feedback may reduce more than 50% the need to feed back data. This is based on the Huffman codes for compressing feedback data jointly with the opportunistic feedback.

In this paper several algorithms for compressing the feedback data, carrying channel quality information and exploiting the inherent frequency and time correlation properties of wireless mobile channels, have been developed and analyzed. These algorithms are developed for a proposed adaptive modulation scheme for future multi-carrier 4G mobile systems. These compression algorithms, used together with opportunistic scheduling, drastically reduce the feedback data rate significantly. Thus,

the adaptive modulation schemes become more suitable and efficient to be implemented in future mobile systems, increasing data throughput and overall system performance. It has also been shown that since the feedback data carries important information, some refresh frames must be sent with certain time intervals in order to avoid error propagation in the decoding process. A reasonable value for the refresh interval may be 15 - 20 frames.

A.1.3 C. Ribeiro, M. J. Fernández-Getino García, V. P. Gil Jiménez, A. Gameiro, and A. G. Armada, Uplink Channel Estimation for Multi-user OFDM-based Systems [16]

This paper resulted from the cooperation between University of Carlos III of Madrid and the University of Aveiro within the framework of COST 289.

OFDM is the choice for a variety of wideband applications due to its robustness against frequency selective channels. In addition, in a multi-user scenario, there exists the so-called multi-user diversity, i.e., the probability that, at least, one user experiences good channel propagation conditions increases with the number of users. If there are many users, it is highly probable that not all of them will experience poor channel propagation and at least one of them will have a good channel. Thus nowadays such multi-user schemes are rapidly growing to improve system efficiency.

Most of the systems require accurate channel estimation either for demodulation/decoding or resource allocation. Usually channel estimation methods are pilot-based, i.e. the channel information is extracted from known transmitted symbols that, although decreasing system efficiency since no data information is conveyed, they provide better performance than blind methods. In centralized networks, this problem is particularly important in the uplink, where multiple users must send pilots efficiently to the access point, so that the multi-user channel estimation can be performed accurately. In order to do so, overlapped pilots may be used for channel estimation where different terminals utilize the same pilot sub-carriers avoiding the decrease in efficiency as the number of users increase. However, the performance results are not very favorable.

This paper proposes a simple, yet flexible and efficient, channel estimator for the uplink in broadband OFDM systems, where several users share the same pilot positions within the frame, with minimal interference among them, but attaining better performance. The system must have dedicated sub-carriers for the transmission of those pilots. Perfect synchronization is assumed at the BS and the channel response is considered constant during each OFDM symbol. The processing is performed in the time-domain, by extracting the Channel's Impulse Response (CIR) for each user from a joint training signal. The estimator can be easily used in either acquisition (preamble-based) or tracking (pilot-tones based) mode, and its structure remains the same for any type of training pattern in the two-dimensional time-frequency space. In this system, the pilot sequence consists of one OFDM-symbol endowed with time-shifted properties per user, which isolates each user's CIR and is robust against multi-user interference. The feasibility of this approach is substantiated by system simulation results obtained using BRAN-A broadband mobile wireless channel model.

A.1.4 S. Sand, C. Mensing, C. Mutti and A. Wittneben Adaptive bit loading and transmit diversity for iterative OFDM receivers [17]

This paper is the result of the joint research between **ETH Zurich and DLR**, Germany, established in the COST 289 environment.

A transmission system is considered to employ OFDM with bit-interleaved coded modulation and perfect channel state information at both transmitter and receiver. An adaptive bit-loading scheme in combination with cyclic delay diversity and discontinuous Doppler diversity is proposed at the transmitter and iterative demapping and decoding at the receiver. The loading procedure minimizes the bit-error rate at the decoder output, and the transmit diversity schemes mitigate channel correlations. The paper analyzes the iterative receiver with extrinsic information transfer charts and presents the achievable gains.

OFDM in combination with bit-interleaved coded modulation (BICM) has turned out to be a robust yet implementation efficient technique for reliable communication over fading channels without channel state information (CSI) at the transmitter. If the transmitter has CSI, e.g., obtained by exploiting channel reciprocity in time-division duplex systems, the negative effects of the fading can be further alleviated by an adaptation of the signaling to the varying channel gain. Water-filling (WF) based adaptive bit loading (ABL) schemes are well-known in the field of transmission over twisted-pair lines. However, practical wireless systems usually operate far from the theoretical capacity. Hence, adaptation policies for such systems should be based on the predetermined coding and modulation schemes rather than accomplishing a WF to maximize the capacity. If we assume that the transmitter has perfect CSI, adaptive techniques to improve the average bit-error rate (BER) performance in environments with frequency-selective fading are proposed. In general, this can only be achieved in low mobility scenarios where the channel is changing slowly. For such channels, a typical environment could be a small office or conference room, where the user is moving slowly. However, this scenario may not offer high frequency-selectivity, and ABL provides only a marginal gain with respect to uniform bit loading (UBL). Cyclic delay diversity (CDD) increases the frequency-selectivity by sending multiple cyclically delayed copies of the original transmit signal over several transmit antennas. The advantages of CDD are that it causes no ISI and a one antenna receiver is sufficient to recover the transmit signal. Compared to orthogonal space-time block codes, CDD needs no additional processing at the receiver and it can employ an arbitrary number of transmit antennas as a rate one space-time code. Thus, ABL together with CDD can yield significant performance gains compared to UBL. In addition, one can employ discontinuous Doppler diversity (DDoD) to increase the time diversity. At the receiver, the system performance can be further improved by iteratively exchanging extrinsic information between the demapper and decoder. The critical design parameter for a BICM receiver with iterative demapping and iterative decoding (IDEM) is the choice of the symbol alphabet mapping, i.e., the labeling map between the bits and the symbol alphabet elements. Extrinsic information transfer (EXIT) charts are used to predict and analyze the performance of IDEM.

This paper presents a study of the effect of correlated channels for an ABL scheme in a BICM-OFDM system with IDEM. It is shown that the ABL scheme can be easily combined with the transmit diversity techniques CDD and DDoD to compensate the

time- and frequency correlations of the channel. Furthermore, the EXIT charts of the ABL scheme are analyzed in combination with the promising IDEM scheme for different mappings. Finally, BER simulations verify the performance gains predicted by the EXIT charts. At an average BER of 10^{-6}, it turns out that the ABL scheme with SP mapping yields a performance gain of about 6.6 dB with respect to UBL with Gray mapping.

A.1.5 M. Stemick and H. Rohling, Effect of carrier frequency offset on the channel capacity in multi-user OFDM-FDMA systems [18]

The 4G of mobile communication systems will have to offer hundreds of Mbit/s of data rate both in the downlink and in the uplink direction in order to meet the demands and requirements of future multimedia applications. This can be fulfilled if the utilized communication system has a high degree of flexibility and adaptivity. OFDM is a very robust transmission procedure in multipath and frequency selective radio channels. A Frequency Division Multiple Access (FDMA) resource allocation technique offers the opportunity of a detailed link adaptation scheme. The combination of these transmission- and multiple access techniques in OFDM-FDMA was found to be a very strong candidate for the downlink of future 4G systems to provide broadband mobile communications and high system flexibility simultaneously. Among all other multiple access schemes, the OFDM-FDMA approach permits a very high degree of adaptivity in frequency selective radio channels combined with a moderate technical system complexity and offers high cell capacities by exploiting the inherent multi-user diversity effect of the system.

However, in order to provide high data rates not only in the downlink but also in the uplink, a number of additional technical challenges have to be met. One of these challenges is the time and carrier synchronization synchronization of all mobile terminals (MT) to the BS inside a single cell. Non-ideal synchronization of the user signals to the carrier frequency of the BS leads to intercarrier interferences (ICI).

An OFDM-FDMA based system divides the available bandwidth into a set of orthogonal, but spectrally overlapping subcarriers. Such a system will be especially sensitive to carrier frequency offsets (CFO). In the uplink, every MT allocates an exclusive set of subcarriers, which is superimposed with all other user signals at the BS to an overall OFDM symbol. If every MT provides an individual carrier frequency offset, strong ICI is observed at the BS. Therefore, a precise synchronization of all MTs to the BS is vital for such a radio system.

This carrier synchronization scheme can e.g. be done in such a way that, in a setup phase, the BS measures the CFO for each MT individually. The measured CFO is then fed back to the MTs, in order to adjust their local oscillators. The actual measurement of the CFO can be done with dedicated signals or blindly. However, such a procedure needs a large measurement overhead and its performance will strongly depend on measurement accuracies. Therefore, in most systems a certain amount of CFO has to be tolerated.

The objective of this paper is to investigate the general impact of CFO to the ICI performance on the uplink of multiuser OFDM-FDMA based systems. An analytical model for the ICI consideration in the uplink of a multiuser OFDM-FDMA based

system is derived. The impact of the carrier frequency offset (CFO) on the performance of a cellular multi-user system with respect to different subcarrier allocation schemes is analyzed. The resulting ICI does not only depend on the amount of CFO introduced from different users, but also on the employed subcarrier allocation scheme. The obtained results show that these effects can be neglected in the system performance as long as the synchronization accuracy is sufficient and the synchronization errors are below 3% of the subcarrier spacing.

A.1.6 M. Wetz, I. Periša, W. G. Teich and J. Lindner, Robust Transmission over Fast Fading Channels on the Basis of OFDM-MFSK [19]

Wireless communication with high-speed trains is a typical scenario for fast fading channels. Future trains are expected to travel at speeds up to v = 600 km/h. Obtaining a reliable channel estimate is very difficult in such an environment. At the same time at least some of the data contains security relevant control information, which requires a very robust transmission scheme. A simple way to solve this problem is to use a modulation scheme, which can be detected noncoherently, and therefore does not need channel estimation at all. For multipath channels, OFDM is known be robust since it avoids ISI.

This paper presents an OFDM-based transmission scheme, which is suitable for robust transmission in fast fading environments, where a reliable channel estimate is impossible or very difficult to obtain. This scheme, which is based on the combination of noncoherently detected MFSK (M-ary frequency shift keying) and OFDM, results in a very simple receiver structure, which does not need any equalization and channel estimation procedure. The drawback of MFSK, also in combination with OFDM, is its low spectral efficiency. This can be compensated by noting the fact that the noncoherent detection of OFDM-MFSK allows an arbitrary phase choice for all subcarriers in the transmitter. One possibility to exploit this degree of freedom is to choose the subcarrier phases such that the peak to average power ratio (PAPR) is reduced. A second possibility is to use the subcarrier phases to transmit additional data. This can be done by differentially modulating the subcarriers that are occupied by the OFDM-MFSK scheme. Both possibilities do not affect the robustness of the underlying noncoherently detected OFDM-MFSK modulation.

A.1.7 D. Marabissi, D. Tarchi, F. Genovese, and R. Fantacci, A Finite State Modeling for Adaptive Modulation in Wireless OFDMA Systems [20]

The consumer interest in multimedia applications and, hence, the increasing demand of high data rate services lead to intense research and development activities in wireless communications. Wireless systems have the capacity to address broad geographic areas without the costly infrastructure required to deploy cabled links. In particular IEEE 802.16 family of standards supported by the WiMAX commercial consortium, concerns the Physical and MAC (Medium Access Control) layers specifications for a Broadband Wireless Access (BWA) communication protocol. WiMAX is considered as one of the most prominent technologies for providing a BWA in a metropolitan area.

While many technologies currently available for fixed BWA can only provide line-of-sight (LOS) coverage, the technology behind WiMAX has been optimized to provide

excellent NLOS coverage by using performance-enhancing technologies. Among these, OFDM has been demonstrated as an efficient way to mitigate the adverse effects of frequency selective multi-path fading by transmitting signals over a number of flat-faded narrow-band channels that are relatively easy to equalize. Among several strategies, the adaptive modulation techniques have been selected for providing an efficient non-line-of- sight (NLOS) coverage.

Adaptive modulation allows the system to adapt the modulation scheme according to the channel conditions in order to enhance the system performance. The inherent multi-carrier nature of OFDM also allows the use of adaptive modulation according to the behavior of the narrow-band channels, in order to improve system capacity, peak data rate, and/or coverage reliability. To exploit fully the advantages of OFDM in wireless systems, dynamic allocation techniques need to be devised in order to efficiently use resources such as bandwidth, power as well as modulation schemes to increase the spectral efficiency. In particular, this paper is concerned with an OFDMA system in which modulation is set separately for each sub-channel based on channel conditions to optimize the use of network resources and enabling a flexible use of resources that can support nomadic or mobile operation.

Adaptive modulation allows the WiMAX system to enhance the throughput of wireless data communication systems, by selecting the most appropriate modulation scheme depending on the propagation conditions of the communication channel, e.g., during good propagation conditions a high order modulation scheme is used in order to increase the data rate transmission while during a signal fade, the system select a lower order modulation scheme to maintain the connection quality and link stability without increasing the signal power. The proposed adaptive techniques are based on the physical channel estimation on the uplink, and selecting the best modulation and coding scheme by using a three state model. The link adaptations algorithms have been introduced with the aim of minimize the SER, maximize the throughput or select the best modulation order for a certain SNR value. The first approach may be appropriate for best-effort services but does not meet QoS requirements in term of error performance. The throughput-based scheme typically yields a higher throughput but the error-base approach provides lower error probability.

This paper deals with the proposal of a state model to be used for the performance comparison of two different adaptation algorithms based on the maximization of different functional costs suitable for use in WiMAX system with an OFDMA physical structure. The algorithms performance has been derived and compared in terms of error rate and throughput. The algorithms show a significant improvement of the system performance compared with the static case, i.e., no adaptive modulation; in particular each algorithm is suited for satisfying different QoS requirements.

A.1.8 V. Bota, Zs. A. Polgar, M. Varga, Performances of the H-ARQ Adaptive-QAM Transmissions over Multipath Channels [21]

The increase of the average throughput and spectral efficiency of the OFDMA schemes under hybrid automatic repeat request (H-ARQ) protocols over mobile radio channels requires a complex approach that involves the following steps:

- employment of an OFDMA scheme whose parameters are adapted to the channel's coherence time and bandwidth;

- adaptive employment of coded QAM modulation;
- selection of powerful high-rate error-control codes;
- optimal setting of the SINR domains where each coded modulation should be employed;
- selection of an user-chunk allocation (access) method that should take the best advantage of the channel's time-frequency and multi-user diversity;
- modeling the multipath Rayleigh-faded mobile channel.

This paper presents an evaluation of the average spectral efficiencies provided by the adaptive use of a set of low-density parity-check (LDPC)-coded QAM modulations in an OFDMA downlink scheme, governed or not by an H-ARQ protocol, over mobile radio channels, considering a joint modeling of the channel and user-access methods. It discusses the selection of the set of coded modulations, briefly describes the joint modeling of the channel and access method employed, and derives the average spectral efficiency provided by this approach in non-automatic repeat request (ARQ) and H-ARQ environments.

A.1.9 M. Deumal, J. L. Pijoan, A. Behravan and T. Eriksson, Evaluation of performance improvement capabilities of PAPR-reducing methods [22],[23]

Marc Deumal from Ramon Llull University visited Chalmers University of Technology during 13.9.2004-29.11.2004 to initiate a joint research on understanding the peak to average power problem in OFDM systems and consequently reducing the PAPR. Ali Behravan from Chalmers University of Technology visited Ramon Llull University during 20.2.2006-12.3.2006. As a result of this cooperation, the conference paper [22] and the paper accepted for the SI [23] are produced.

One of the major drawbacks of multicarrier systems is the large envelope fluctuations which either require an inefficient use of high power amplifiers or decrease the system performance. PAPR is a very well known measure of the envelope fluctuations and has become the cost function used to evaluate and design multicarrier systems. Several PAPR-reducing techniques have been proposed with the aim to alleviate back-off specifications or increase the system performance. Besides the fact that these techniques have varying PAPR-reduction capabilities, power, bandwidth and complexity requirements, it is interesting to notice that the performance of a system employing these techniques has not been fully analyzed. This paper presents a theoretical framework for both PAPR and the distortion introduced by a nonlinearity, and then simulation of an OFDM system employing several well-known PAPR-reducing techniques from the literature. The theoretical analysis and the simulation results show the relation between PAPR and the performance of OFDM systems when a clipping device is present and the real performance improvement capabilities of the PAPR-reducing methods. The agreement between the theoretical and the simulation results demonstrate the validity of the analysis.

OFDM is a powerful modulation technique being used in many new and emerging broadband communication systems. The major advantages of this technique include robustness against time dispersion in multipath fading channels, high spectral efficiency and efficient implementation. The downside is the large amplitude

variations of the OFDM signal, which requires large back-off in the transmitter amplifier and, as a consequence, inefficient use of high power amplifiers (HPA).

In order to reduce the distortion caused by a HPA without setting it to large back-offs, several techniques have been introduced that limit the peak of the signal envelope, a problem that is usually referred to as PAPR reduction. Besides the fact that these techniques have varying PAPR reduction capabilities, power, bandwidth and complexity requirements, it is important to notice that the performance of a system employing these techniques has not been fully analyzed. PAPR is a very well known measure of the envelope fluctuations of a multicarrier signal and has become the figure of merit used in the literature to define the goodness of a method. As a result, the problem of reducing the envelope fluctuations with the aim to increase the system performance (reduce both BER and the out-of-band radiation) has turned to reducing PAPR.

This paper presents a quantitative study of both the PAPR and the performance of an OFDM system when a clipping device is present. PAPR-reduction is meant to decrease the distortion introduced by a nonlinearity and, therefore, reduce both the out-of-band radiation and the BER degradation. However, it is shown, in this paper, that the effect of a nonlinearity in an OFDM signal is not clearly related to its PAPR. In some recent contributions other measures of the envelope fluctuations of multicarrier signals, such as the cubic metric (CM) and the variance of the instantaneous power (VP), have been proposed. The motivation for CM relies on the fact that the major distortion is caused by the third order intermodulation product while the motivation for VP metric is to reduce the envelope fluctuations. It is shown that, except for large back-offs, CM and VP are more related to the amount of distortion introduced by a nonlinearity than PAPR. Moreover, after analyzing certain OFDM-type signals that are considered to meet the long-term evolution (LTE) goals for 3GPP networks, it is shown that PAPR does not predict HPA power de-rating as accurately as CM. Power de-rating is understood as the amount of power back-off needed in the HPA to meet a given adjacent channel leakage ratio (ACLR) level.

This paper also compares the BER performance and the PSD of a conventional OFDM with that of a PAPR-reduced OFDM system. The results show that the spectral outgrowth is reduced when applying PAPR-reduction but that a BER performance improvement only occurs when the effect of reducing the in-band distortion is more important than the loss of power efficiency. However, since CM and VP are shown to be more related to the amount of distortion introduced by a nonlinearity than PAPR, it is believed that the performance of the PAPR-reducing techniques in the literature can be improved by reformulating them to CM/VP-reduction.

A.1.10 J. Krajnak, P. Pavelka, D. Kocur, P. Galajda, M. Deumal and J. L. Pijoan, Multi-user detection of nonlinearly distorted MC-CDMA sysmbols by microstatistic filtering [24]

The visit by STSM program of **Marc Deumal** to the Technical University of Kosice resulted in the paper [24] presented in the 4th Workshop and accepted for the SI.

Multi-carrier code division multiple access (MC-CDMA) is a powerful modulation technique that is being considered in many emerging broadband communication systems, since it exploits the advantages of spread spectrum (SS) and OFDM. One of the major disadvantages of multi-carrier (MC) systems based on OFDM is the high sensitivity to nonlinear amplification, which requires large back-off in the transmitter amplifier and, as a consequence, inefficient use of power amplifiers. On the other hand, using low back-offs leads to signal distortion and, as a result, increased performance degradation.

In a downlink scenario, orthogonal spreading sequences are used since they reduce multiple access interference (MAI) compared to non-orthogonal. However, the nonlinear amplification of the transmitted signal destroys the orthogonality and, thus, reduces the system performance. Particularly in the synchronous downlink, where orthogonal spreading codes are used to reduce the MAI, the nonlinearity (NL) destroys the orthogonality thus increasing MAI. In order to avoid performance degradation without requiring large back-offs in the transmitter amplifier, it becomes necessary to use multi-user detection techniques at the receiver side. Conventional multi-user detectors (MUD) are designed for linear environments and, as a result, might not exhibit enough performance improvement.

Several techniques can be found in the literature to reduce the sensitivity of MC-CDMA systems to nonlinear amplification. Most common transmitter side solutions include predistortion and PAPR reduction. Receiver side strategies usually combine iterative decoding and multi-user detection so that both NL compensation and MAI is taken into account. In that sense, MUD that performs a joint detection, estimation and cancellation of the nonlinear distortion effects and a receiver based on an iterative block decision feedback equalizer, combined with estimation and cancellation of the nonlinear distortion effects was proposed. The major drawback of such solutions is that they increase significantly the complexity requirements at the receiver side. Complexity is mainly given by the number of iterations, which, in fact, increases with the number of active users. Moreover these techniques require that predistortion is used at the transmitter side. In order to reduce the complexity requirements it is proposed to iteratively optimize the signal constellation of each active user, via a multi-user approach, such that the intersymbol interference (ISI) at the relevant decision devices is minimized. However, this approach also requires predistortion at the transmitter side.

In this paper a new MUD based on microstatistic filtering is proposed. The presented MUD uses piece-wise linear filtering in conjunction with threshold decomposition of the input signal, which introduces a nonlinear effect, to improve performance when a nonlinearity is present. The key idea is to use a nonlinear but piece-wise linear structure in order to model the nonlinear behavior of the transmitter's power amplifier with high flexibility and simplicity. Then, prior to the detection stage, compensation of the received complex valued symbols is done. The transmitter's NL is modeled by using a training sequence and following the minimum mean-squared error (MMSE) criterion. Simulation results show that the proposed detector outperforms conventional linear ones when low spreading factors (SF) and user loads no greater than 50% are used. For other system configurations, similar performance is obtained. This improvement is achieved at the expense of an acceptable increase of the computational complexity in comparison with that of conventional MMSE-MUD.

Nevertheless, the complexity requirements of a MSF-MUD based receiver are much smaller than those of previously proposed approaches. Moreover, the proposed scheme neither requires predistortion at the transmitter nor iterative decoding at the receiver.

In this paper the performance of the proposed MUD is also compared with that of a conventional MMSE-MUD when a NL is present. Simulation results suggest that the performance of MSF-MUD is always better than or, at least, equal to that of MMSE-MUD. However, large performance improvement is achieved for low SFs and user loads no greater than 50%. Although this improvement is obtained at expenses of increasing the receiver computational complexity, it has been shown that a minimum increase of the complexity requirements with respect to MMSE-MUD is enough to achieve noticeable performance improvement in nonlinear AWGN channels.

A.1.11 M. Karaman-Colakoğlu and M. Şafak, On the MIMO Channel Capacity Predicted by Kronecker and Müller Models [25]

MIMO systems provide significant improvements in the capacity of wireless communication systems. However, an accurate model of the MIMO channel is needed for a realistic assessment of the capacity. The MIMO channel capacity may be described in terms of the number and the spacing of transmit and receive antennas and the scattering richness (which is related to the number and the geographical distribution of the scatterers). Since rays undergo significant amounts of attenuation each time they are scattered, the channel capacity is also influenced by the number of times the transmitted rays are scattered in the propagation process.

This paper presents a comparison between the outage capacity of MIMO channels predicted by the Kronecker and Müller models as a function of the number of scatterers, transmit and receive antennas.

In the Kronecker model, which applies for a flat-fading MIMO channel, the rays are assumed to be scattered twice before arriving at the receiver; thus direct and the single-scattered rays are ignored. In this model, fading correlations are separated at transmit and receive antenna arrays and in the channel. Since this model considers only the rays scattered from both transmit and receive scatterers, it may be more appropriate for radio propagation in urban areas. However, it may lead to pessimistic predictions in suburban channels, where direct- and/or singly-scattered rays may also reach the receiver. Some measurement results are reported to show that this model fails under certain circumstances.

The Müller model is an asymptotic random channel model for a frequency selective fading MIMO channel, where only singly scattered rays are considered. The Müller model is characterized by the number of scatterers and of transmit- and receive antennas; these parameters uniquely determine the channel capacity. The Müller model is simpler and is characterized by the scattering richness and the numbers of transmit and receive antennas. Since it considers only the singly-scattered rays, this model may describe a suburban channel more accurately.

The two models are compared as a function of the number of scatterers, transmit- and receive antennas and the SNR per receive antenna. Additional parameters needed for characterizing the Kronecker model are assumed fixed for comparison purposes. Noting that singly-scattered rays undergo less attenuation compared with multiple-scattering, the capacity predictions by the Müller model were observed to be higher compared with the Kronecker model. It may even overestimate the capacity in urban channels where rays undergo mostly multiple-scattering. In this model, the scattering richness plays an important role, which is usually ignored in other models. An increase in the number of receive antennas leads to an improvement in the outage capacity predicted by both methods but the rate of improvement tapered with increasing values of the number of receive antennas. The capacity predictions by both methods were observed to improve with increasing values of the number of scatterers and the SNR ratio. The Kronecker model shows a steady improvement in the outage capacity as the transmit array size increases, while the Müller model behaves differently for different values of the outage capacity. When the transmit array size is higher than the receive array size, the channel capacity, predicted by the Müller model, was observed to increase with the increasing number of transmit antennas for low capacity values, but to decrease for higher capacity values. When the transmit array size is less than the receive array size, the outage capacity was observed to decrease with increasing transmit array size. These results need to be supported by measurements in realistic scenarios.

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A.2. PERVASIVE WIRELESS ACCESS FOR 4G

Next generation WLANs will provide ubiquitous wireless connectivity for a variety of heterogeneous nodes, e.g., RFID tags for object identification, sensors and computers, with data rate requirements ranging from 1Mbps to 1Gbps. This breed of networks is referred to as *pervasive wireless access networks*, which are believed to have a tremendous impact on our lifestyle. It is anticipated that, in the future, pervasive wireless access systems will generate the bulk of the data traffic in the Internet.

Pervasive wireless access networks are based on short-range wireless communication technology and provide ubiquitous wireless connectivity for a variety of heterogeneous nodes. Existing systems include Wireless Local Area Networks (WLAN), Wireless Personal Area Networks (WPAN), Wireless Sensor Networks (WSN), RF identification (RFID) and automotive communications. Pervasive wireless networks introduce fundamentally new characteristics and requirements. They challenge many "proven" approaches to wireless network design.

For complexity reasons, low-end user nodes will have a single antenna. High-end user nodes will feature multiple antennas to improve throughput and coverage. The

extended use and range of deployment will lead to a high node density. This makes cooperative signaling schemes an extremely attractive option. Channel adaptive scheduling, adaptive modulation and spatial multiplexing will be indispensable to achieve the required scalability and spectral efficiency. The heterogeneous QoS requirements would facilitate channel adaptive scheduling, but typical user nodes in wireless local area networks (WLANs) have low mobility and the channel may not vary sufficiently over time to make fair channel adaptive scheduling efficient.

For spectral reasons, next generation WLANs will operate beyond 5 GHz (e.g. at 17/24GHz). Here, we face a *poor scattering/rich array* situation as opposed to the *rich scattering/poor array* situation at 5GHz [1]. Recent work [2]-[4] has shown the potential of cooperative signaling (in particular linear multi-node relaying) to exploit spatial multiplexing on poor scattering channels.

The main motivation of this project is to open up the benefits of cooperative diversity, channel adaptive scheduling and spatial multiplexing (MIMO) in a low mobility environment with poor scattering and heterogeneous nodes. This area is essentially unexplored to date and requires fundamental new work ranging from multinode/multihop channel modeling to efficient cooperative spatial multiplexing, cooperative medium access and cooperative channel adaptive scheduling schemes. In this project, attention is given to linear but possibly *time-variant* processing at the cooperating nodes. This has the major advantage that the cooperation is transparent to an adaptive modulation scheme (symbol alphabet) used by the source. These schemes allow a seamless integration of multi-antenna nodes and remain efficient in a poor scattering environment.

The area of interest of this project includes multihop/multinode channel model implementations, cooperative space-time code design criteria and evaluation software, cooperative WLAN simulation framework), (cellular) relay networks, (cross-layer solutions to) sensor networks, cooperative communications, scheduling for cooperative relaying networks The proposed research benefited substantially from the RACOON Laboratory and the test bed infrastructure [5][6], which is made available in ETH Zurich to COST289 researchers for verification and demonstration activities.

A.2.1 J. Zhao and A. Wittneben, Cellular Relaying Networks: State of the Art and Open Issues [7]

Future wireless communication systems are expected to provide more stable and higher data rate transmissions in the whole network. Recent research shows that it is advantageous to use relay stations in wireless networks in order to satisfy that need. But due to the limited power supply of mobile users, it may be difficult for the users to act as relays. Thus placing additional fixed relay stations to assist the communications is an attractive way for the cellular network solution.

The concept of relaying has been a well-known technique for transmission of signals over very long distance. Research results on relay channels can be found in the 1970's. Recently, due to the explosion of interests in ad hoc networks and the research activity on the 4G wireless communication systems, the concept of relay networks was again brought to the mainstream of research in mobile communication academy and industry. That is because of the following reasons: First, the envisioned

transmission rate of 4G systems is several orders of magnitude higher than that of the current mobile communication systems. With the same power level, the transmitted power per bit will be just a small fraction of that in current systems. It is unlikely that 4G mobile systems can cover the same service area without additional infrastructure. Second, the spectrum to be released for 4G systems will be far above the spectrum of current mobile systems. The problem of path-loss will prohibit the BS from communicating with users far away. One way to overcome those problems is to use relays to extend the coverage area in cellular networks.

In addition to the previously mentioned reasons, recent research has shown that the deployment of relays can enhance the capacity of wireless networks and improve the overall data rate. By introducing relay stations, additional transmission paths are created. Signals carrying the same information are transmitted over independently fading channels and can be combined at the receiver. Thus multi-hop communication can realize spatial diversity in distributed antenna systems such as cellular networks to improve the stability of radio links between the BS and users. The integration of relay networks into conventional cellular networks is perhaps the most promising wireless architecture in the years to come. Due to the limited power supply of mobile users, it is difficult for the users to act as relays in future wireless networks. One feasible solution is to place fixed relay nodes on the top of lampposts or high buildings where good wireless connection with the BS is possible. They can have sufficient power supply and can be equipped with powerful signal processing hardware as well as multiple antennas.

The aim of this paper is to present the state of the art for cellular relaying networks. The paper describes the basic and the most commonly used relaying protocols that combat the fading channel induced by multipath propagation in wireless networks. Subsequently, a cooperative transmission scheme for cellular downlink is discussed based on the assumption that the BS is equipped with multiple antennas. Using space-time coding techniques, the benefits of multiple-input-multiple-output (MIMO) communication can be achieved. A strategy to combine the benefits of cellular and *ad hoc* networks using relaying stations is also discussed. Such a network can successfully divert traffic from one ”hot spot” cell to another cell, which is not congested. An example of a cellular relaying network called wireless media system (WMS) is presented. Such a network divides the cells into pico-cells with the help of fixed relays, which can be easily integrated into next generation cellular networks. Future cellular relaying protocols may also require joint optimization of cross layer design. Finally, a discussion of some open problems is provided.

A.2.2 M. Rydström, L. Reggiani, E.G. Ström and A. Svensson, Adapting the ranging algorithm to the positioning technique in UWB sensor networks [8]

Ultra-Wideband (UWB) is an emerging technology for short-range wireless communications. Due to the high bandwidth of UWB signals, accurate ranging and positioning is possible. This is one of many reasons why UWB is a candidate physical layer for another emerging research area, i.e., wireless sensor networks (WSNs). In this work, it is argued that the ranging algorithm design should be made with the characteristics of the positioning algorithm in mind. In considering ranging and positioning in parallel, one can construct a range estimator that is tailored to the positioning algorithm, thereby achieving robustness to non-line-of-sight (NLOS)

effects, reasonable overall complexity, and good performance in terms of positioning error.

In a WSN, information about the position of individual nodes, either absolute or in relation to other nodes in the network, is often crucial for a successful fulfillment of the network purpose. One of the candidate physical layers for this type of network is ultra-wideband impulse radio (UWB-IR), that potentially combines low power consumption, immunity to multipath fading, low probability of intercept, and, supposedly, low cost. Due to the large bandwidth employed by UWB-IR, accurate propagation delay based ranging between nodes is feasible. Such distance estimates may then be used to estimate the positions of nodes in the network. However, many obstacles need to be overcome before a successful WSN positioning system can be realized;

(a) Most WSNs will be asynchronous, meaning that there is no available global time reference accurate enough for direct propagation delay distance estimation.
(b) The channel statistics must, in most cases, be assumed unknown at the receiver.
(c) There are tight constraints on energy consumption, cost and size, limiting the allowable complexity.
(d) Devices will most likely not be homogenous, i.e., different types of receiver front-ends will be present in the network.
(e) A given percentage of channels will be non-line-of-sight (NLOS), adding a considerable positive bias to most distance estimators.

An extensive literature exists on the topic of ranging and positioning in UWB systems. This work differs from the work in the literature in several aspects, the assumption of prior information about the channel being the most significant. In this paper, improvements in both positioning accuracy and robustness are shown to be possible if the error characteristics of the ranging scheme can be adapted and matched to the characteristics of the positioning scheme. Towards this end, a novel ranging algorithm, that operates without a global time reference and assumes no prior channel knowledge is designed. The algorithm does not output a single distance estimate, as most proposed algorithms in the literature do, but several distance estimates with associated likelihoods. Using these ”soft” distance estimates, one can tune the error distribution to suit a given positioning algorithm. The positioning algorithm used as an example here is based on projections onto convex sets, a method that is remarkably resilient to arbitrarily large *positive* errors in distance estimates, but suffers if large negative errors in distance estimates occur. Hence, the distance estimator is tuned to output a minimum of estimates with negative errors, at the expense of intermittent large positive errors and higher variance. Other positioning algorithms, such as least-squares approaches, do not have this peculiarity, and thus the distance estimator is tuned differently.

The analysis and simulations in this work are based on the channel models adopted by the IEEE 802.15.4a Working Group, and highlight the benefits and drawbacks of the proposed approach. In this work, the advantages of adapting the physical layer distance estimator to the characteristics of a positioning algorithm are investigated. This approach lead to a ranging and positioning system that offers low complexity

and good performance, while being robust to multipath, NLOS channel effects and objective function local minima.

A.2.3 F. Chiti et al., D-STAR MAC Protocol: a cross layer solution for wireless sensor networks endowed with directive antennas [9]

Wireless sensor networks (WSNs) have been attracting a great deal of scientific interest in the last decade, making of this approach an enabling technology to the aim of intelligent environments instrumenting. The deployment of networks, comprised of tens up to thousands of sensors, currently represents an affordable solution to some challenging problems: environmental sensing, productive chains control, real-time phenomena monitoring, and safety and rescue applications. Though WSNs represent a special case of the more general wireless ad hoc networks, they differ from it in additional constraints, as they have limited energetic, storage, processing and communication capabilities, the low degree of mobility and the presence of a small number of sinks. However, recent advances have lead to the emergence of distributed wireless sensor and actor networks (WSANs), which allow for enhanced capabilities of observing, data processing and making. This represents a more critical scenario because the usual impairments of ad hoc communications must be taken also into account.

This innovative paradigm basically relies on an underlying paradox claiming at pursuing reliable tasks through intrinsically unreliable actors. This challenge can be solved by careful system design with particular regard to the communications and control protocols. This is of particular relevance whenever advanced interaction and sensing schemes are applied as it happens in the case of WSANs or mobile WSNs. Among the most promising criteria to be adopted, the proper management of both sleep- and active-states and the introduction of directional antennas and their integration within the communications framework play a key role. As these aspects belong to both the Physical (PHY) and Medium Access Control (MAC) layers, they might be integrated to reach an overall energy efficiency, jointly managing the duty cycle and the transmitting and receiving antenna gains. A novel and promising approach to accomplish this task relies on the so-called cross-layer protocol design principle.

This paper aims at filling this gap by proposing a novel MAC layer protocol, namely Directive Synchronous Transmission Asynchronous Reception (D-STAR), that broadens the previously introduced STAR approach toward the management of directive antennas neither increasing the signaling overhead nor affecting the set-up latency, but achieving energy consumption reduction and remarkable lowering of collision probability. D-STAR protocol is thus able to logically synchronize a WSN. To this end, the cross-layer principle has been adopted to design a protocol that adapts physical parameters (as the antenna main lobe) to the link-to-link communications features and, on the other hand, provides a nodes' logical synchronization by explicitly taking into account the antenna capabilities.

D-STAR protocol has been characterized in terms of functional characteristics and the overall performance is presented in terms of network lifetime gain, set-up latency and collision probability. A remarkable improvement is obtained with respect to the basic approach endowed with omnidirectional antennas without increasing the signaling

overhead nor affecting the set-up latency, but achieving energy consumption reduction.

Future developments of the present research activity might include the protocol implementation and testing over realistic user defined scenarios as well as the application to fields different from the environmental monitoring as the emergency operations with specific requirements.

A.2.4 S. Plass, G. Richter and A. J. H. Vinck, Coding schemes for crisscross error patterns [10]

In a number of applications, the following error protection problem occurs: The information symbols have to be stored in (N x n) arrays. Some of these symbols are transmitted erroneously in such a way that all corrupted symbols are confined to a specified number of rows or columns (or both). We refer to such errors as crisscross errors. These crisscross errors can be found for example in memory chip arrays or in magnetic tape recording.

This paper addresses two coding schemes, which can handle emerging errors with crisscross patterns. First, a code with maximum rank distance, so-called Rank-Codes, is described and a modified Berlekamp-Massey algorithm is provided. Secondly, a Permutation Code based coding scheme for crisscross error patterns is presented. The influences of different types of noise are also discussed.

Since the Hamming metric is not appropriate for these error patterns, the rank of a matrix is used as a metric for error correction purpose. Rank-Codes with maximum rank distance are introduced that are capable of correcting a specified number of corrupted rows and columns. Rank-Codes cannot only correct erroneous rows and columns, they can even correct a certain number of rank errors. The number of rank errors is defined as the rank of the error array.

Furthermore, it is also possible to define a Permutation Code in which each codeword contains different integers as symbols. This code can be applied to the crisscross error problem. This paper describes the Rank-Codes and introduces a modified Berlekamp-Massey algorithm for Rank-Codes as an efficient decoding procedure for decoding rank errors. A Permutation Code for crisscross patterns, its applications, and the effects of different types of noise are also addressed.

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[10] S. Plass, G. Richter and A. J. Han Vinck, Coding schemes for crisscross error patterns, presented in 4th COST Workshop held in Gothenburg during 11-12 April 2007, and accepted for publication for the Special COST289 Issue of Wireless Personal Communications, early 2008.

A.3. SOFTWARE DEFINED RADIO

Optimized control, management and flexibility of future network infrastructures, will support

- evolution towards adaptive/cognitive networks,
- transparent operation across different operators and technologies,
- reconfigurability of resource allocation and self organization,
- real time ad-hoc communications,
- intelligent distribution of services across multiple access technologies,
- distributed mobility management schemes; the provision of location services; and power management.

The above-cited features require logical functions, coordination mechanisms and systems architectures better suited for adaptation. On the other hand, wireless systems access a great number of networks operating according to different standards. Inter-system roaming (e.g. GSM-IS95) and vertical handover (e.g. UMTS-WLAN) would require the implementation of many different standards in a single radio terminal/BS.

In order to avoid the usage of multi-mode terminals, the so-called software defined radio (SDR) concept has been proposed. Reconfigurable equipment with universal hardware and downloaded software can solve roaming/handover problem efficiently. Furthermore, modifications or even new techniques related to the air interface can be realized without effort enabling cost-efficient system upgrades. Therefore, SDR fits into the newly emerging "reconfigurable networks" concept.

The SDR implies a radio with enough programmability, thus easy and inexpensive modification of the signal processing steps, and thereby provides different communication schemes. Thanks to the developments in digital signal processing (DSP), field programmable gate arrays (FPGAs), application specific integrated circuits (ASICs) and digital signal processors (DSPs), we now have new options for the SDR. The ability to work across a wide range of frequency spectrum is believed to be a requirement for next generation SDR's. Hardware architectures, for both baseband and RF sides, continue to improve. The SDR technology continues to evolve and is expected to be one of the key technologies for the future systems.

Within COST 289 the following research topics are considered:

- Hardware strategies to efficiently design reconfigurable radios (implementation independent methods). Consequently, the efforts are focused in:
    - The physical layer organization (distributed-DSP or centralized INTEL-type approaches) [1], [2]
    - More general approaches, including higher layer protocols, networking, services, interfaces, call admission control, etc
- Software strategies for downloading software modules and efficient reconfiguration algorithms.
- Specific hardware architectures that allow reconfiguration with a minimum power consumption penalty [3] or dynamic adaptation to the variations in user traffic.
- Experiences that partially implement multiple standards as GSM, EDGE, WCDMA-FDD, Bluetooth using some strategies on any platform ([2], [4], [5], etc.)
- Adaptive systems that make possible the coexistence of different standards in the same platform [6]-[8].

In addition to the above research activities, the SDR project aims to cooperate with the other two projects, namely *Pervasive Wireless Access for 4G* and *Wide Area Coverage and High Mobility Access Systems for 4G*, which consider vertical approaches in wireless networks in two different environments (low versus high mobility, centralized versus distributed). The SDR project provides a bridge these two COST 289 projects horizontally, concentrating in the reconfigurability of different systems.

The researchers came together in a STSM from 25-29 October 2004 in UPC, Barcelona, to discuss the potential research topics and possibilities of cooperation.

During 1st COST289 Workshop, held in Budapest, 7-9 July 2004, a special session was dedicated to discuss the research cooperation in SDR between the participants. During this Workshop, Prof. J.L. Pijoan gave an invited seminar entitled Software

Radio: An Enabling Technology for Mobile Communications. Prof. A. Polydoros, from Technical University of Athens, gave an invited seminar entitled Radio Flexibility at the PHY Layer, during the 2nd COST289 Workshop, held in Antalya, 6-7 July 2005.

A.3.1 I. Safak and M.Üner, Turbo decoding on the TMS320C6416 digital signal processor [9]

This project is concerned with the implementation of a 3rd Generation Partnership Project (3GPP) M-PSK modulated turbo coded system in a multipath Rayleigh fading channel on a TMS320C6416 Digital Signal Processor (DSP) Starter Kit (DSK). The turbo decoder coprocessor (TCP) integrated into the Texas Instruments DSP is employed. The MATLAB link for Code Composer Studio (CCS) is used to acquire outputs from the DSP. The performance of such a system was measured in AWGN channel.

A.3.2 C. Vilella, and J.L. Pijoan, Software radio: An enabling technology for mobile communications [10]

SDR represents a class of reprogrammable or reconfigurable radios, where the same piece of hardware can perform different functions at different times. It is substantially defined in software and its physical layer behavior can be significantly altered through changes to its software. It accepts fully programmable traffic and control information and supports a broad range of frequencies, air-interfaces and applications software. It is sufficiently flexible so that new and different standards or protocols can be implemented through reprogramming. Emerging and evolving technology enables flexible radio systems, providing multiple services, multiple band operations, and reconfigurability and reprogram ability using software.

SDR provides software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as hopping), and waveform requirements of current and evolving standards over a broad frequency range. The frequency bands covered may still be constrained at the front-end requiring a switch in the antenna system.

Ideal software radio (ISR) provides dramatic improvement over an SDR by eliminating the analog amplification or heterodyne mixing prior to digital-analog conversion. Programmability extends to the entire system with analog conversion only at the antenna, speaker and microphones.

Ultimate software radio (USR) accepts fully programmable traffic and control information and supports a broad range of frequencies, air-interfaces and applications software. It can switch from one air interface format to another in milliseconds, use GPS to track the user's location, store money using smartcard technology, or provide video so that the user can watch a local broadcast station or receive a satellite transmission.

A.3.3 A. Polydoros, Radio Flexibility at the PHY layer [11]

In response to the demand for increasingly flexible radio systems from industry (operators, service providers, equipment manufacturers, chip manufacturers, system integrators, etc.), government (military communication and signal-intelligence systems), as well as various user demands, the field has grown rapidly over the last twenty years or so, and has intrigued and activated R&D Departments, academia, research centers, as well as funding agencies. It is now a rapidly growing field of inquiry, development, prototyping, and even fielding. Because of the enormity of the subject matter, it is hard to draw solid boundaries that exclusively envelop the scientific topic, but it is clear that such terms as Software Radio, Software Defined Radio, Reconfigurable Radio, Cognitive/Intelligent/Smart Radio, etc., are at the center of this activity. Similar arguments would include work on flexible air-interface waveforms and/or generalized (and properly parameterized) descriptions and receptions thereof.

Among the many factors that seem to motivate the field, the most obvious seems to be the need for multi-standard, multi-mode operation, in view of the extreme proliferation of different and mutually-incompatible radio standards around the globe (witness the analog-to-digital-to-wideband-to-multicarrier evolution of air interfaces in the various cellular-system generations). This is the desire for "legacy-proof" functionality, i.e., the ability to handle existing systems in a single unified terminal (or single infrastructure access point), regardless of whether this radio system is equipped with all the related information pre-stored in memory or whether this is software-downloaded to a generically architected terminal. In a similar manner, "future-proof" systems would employ flexibility in order to accommodate yet-unknown systems and standards with a relative ease (say, by a mere re-setting of the values of a known set of parameters), although this is obviously a harder goal to achieve. Similarly, economies of scale dictate that radio transceivers employ reusable modules to the degree possible ("modularity"). Of course, truly optimized designs for specific needs and circumstances lead to "point solutions", so that flexibility of the modular and/or generic waveform-design sort may incur some performance loss. In other words, the benefit of flexibility may come at some cost, but hopefully the trade-off is still favorable to flexible designs.

This paper considers only the physical-layer aspect of radio flexibility and provides a brief description of various research fronts at that layer, with particular emphasis on the digital baseband and the algorithms/tasks that this portion may perform in the service of flexibility. It starts by identifying the various goals of flexible radio and then provides some definitions for a systematic sorting out of the related concepts. It delineates the various research sub-areas that have recently been identified as central to promoting the relevant research methodology, namely:

- Flexible baseband digital signal processing algorithms.
- Flexible digital platforms and architectures.
- Flexible Link-Centric QoS management concepts.

For each sub-area, various open issues and knowledge gaps are identified. In addition, a generic framework for the description and taxonomy of the various flexibility

mechanisms are presented, including a discussion of the various related metrics and cost functions.

Finally, *dynamic signal design* is presented as an example of a mechanism that empowers such flexible transceiver architectures, providing for mode-selection algorithmic designs that incorporate these concepts and thus represent an instantiation of the radio flexibility framework.

A.3.4 M. Safak, Towards cognitive communications, A COST Action Proposal [12]

In contrast with existing systems, which are static, future communication systems are expected to embrace *adaptivity* so that they can self organize in changing environments and operating conditions in order to cope with increasing subscriber population and service demands. Adaptation strategies (bio-inspired, stochastic or others) may operate at different time scales and speeds, from short-term adaptation to long-term evolution, and may imply changes in software, hardware, protocols and/or architecture.

Adaptive resource allocation exploits inherent system diversities, typically resulting from time- and frequency-selectivity of wireless channels, independent fading of multiple user signals, parallel channels in the space and frequency domains, random traffic arrival, user mobility, as well as the interaction between different network layers. Link adaptation adapts modulation, coding, transmit power, and/or other signal transmission parameters to the instantaneous channel conditions, aiming to increase spectrum efficiency and reliability of wireless systems.

In a typical network, adaptations are reactive, i.e., take place after a problem has occurred. A *cognitive network,* using a cognitive process, can observe, perceive current network conditions, then develop a capability to learn from past decisions and use this capability to optimize the end-to-end performance by changing one or more modifiable elements. While a *cognitive radio* depends on software-defined radio (SDR) to modify aspects of radio operation (e.g., RF bands, channel access modes, channel modulations, bandwidth, code, waveform), a *cognitive network* aims end-to-end performance optimization, which is achievable only by cross-layer protocol designs.

The layered protocol designs do not necessarily lead to optimal performance in adaptive/cognitive systems. Different coding, modulation, diversity, and other error control schemes may be used to improve the PHY performance. However, network performance may be significantly improved by the mutual adaptation of coding and modulation on the PHY, MAC and buffer service capacity on the (data) link layer, and routing strategy on the transport layer.

Cross-layer protocol designs are based on direct communication and sharing of internal information between non-adjacent layers, for the efficient management of system resources. Some components on the PHY must then be designed so that higher layers can access and/or control them. Alternatively, several protocol layers can be merged into one layer. The first approach keeps the transparency between protocol layers, while the second approach can achieve much better performance through

closer interaction between them. Cross-layer protocol designs make hardware design more challenging; have risks due to the loss of protocol-layer abstraction; incompatibility with existing protocols; unforeseen impacts on the network design; and difficulty in maintenance and management. However, future cognitive systems will definitely incorporate cross-layer designs.

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ANNEX B

LIST OF PUBLICATIONS

B.1 PRESENTATIONS MADE IN MCMs and COST289 WORKSHOPS

1. M. A. Dangl, W.G. Teich, J. Lindner and J. Egle, Joint Iterative Equalization, Demapping and Decoding with a soft Interference Canceller
2. D. Galda and H. Rohling, A Low Complexity Transmitter Structure for OFDM-FDMA Uplink Systems
3. B. Chen and H. Rohling, Joint Layer Optimization for OFDM based Radio Systems
4. L. G. Alonso Zarate, MAC/RLC Protocol Design in Heterogeneous Networks
5. S. Bozay and M. Safak, Performance Analysis of Spatial Multiplexing and Maximal Ratio Combining Systems in the Presence of Polarization Diversity
6. A. Svensson, A. Ahlen, A. Brunstrom, T. Ottosson and M. Sternad, An OFDM based System Proposal for 4G Downlinks
7. M. Sternad, T. Ottosson, A. Ahlen and A. Svensson, Attaining both Coverage and High Spectral Efficiency with Adaptive OFDM Downlinks
8. W. Wang, T. Ottosson, M. Sternad, A. Ahlen and A. Svensson, Impact of Multiuser Diversity and Channel Variability on Adaptive OFDM
9. M. des Noes and D. Ktenas (presented by Sylvie Mayrargue), MC-CDMA vs DS-CDMA
10. Stephan Sand, Two Dimensional Pilot Symbol Aided Channel Estimation for a Broadband MC-CDMA System with High Mobility
11. A.J. Han Vinck, Pulse Position Access Codes
12. Pavol Švac, Martin Piekov, CC-CDMA for B3G Wireless Communications : An overview and some open isuues
13. Dušan Kocur, Jana Cízová, Stanislav Marchevsky, The Piece-Wise Linear Microstatistic Multi-user Receiver
14. F. Chiti, R. Fantacci, G. Mennuti, and D. Tarchi, A Novel Admission Control Algorithm for UMTS System
15. Arne Svensson, Joint project on ”Wide area coverage and high mobility access systems for 4G”
16. F. Adelantado, O. Sallent, J. Pérez-Romero, R. Agustí, Traffic Hotspots in UMTS networks: influence on RRM strategies
17. Simon Plass, Rank-Codes for OFDM
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19. Stefan Wendt, A tapped Delay Line Model of Multipath Channel for CDMA Systems
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