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OPLINK: Net Centric Optimization TIN2005-08818-C04

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Abstract

This project aims at profiting from the present wealth and advanced knowledge in combinatorial optimization to solve problems of high impact in academics, industry, and society. In a world of high connectivity, networks and communications are worthy fields to make research in, and this is why we target them here. Our main goal is indeed to detect what are the actual hard problems in the core of different net centric applications, and since most times they are of a combinatorial nature, we are using exact, metaheuristic and, in general, whatever new techniques that might lead to solve them in an efficient and accurate way. By net centric we mean both communication (e.g. 2G/3G) and data networks (e.g. grid computing). Also, we are addressing, not only problems in networks having a provider, but also in ad hoc domains with peer to peer connections. In practice this means: GSM network design, cellular and satellite channel/frequency allocation, mobile/ad-hoc network design (MANET and vehicular), routing, grid technologies, parallel computing, and related applications.

We go one step further and work for a second goal: transfer to the industry of the resulting techniques and software, what will require dealing with very hard restrictions, fast response, and customer demands. As a third important goal we are progressing towards robust methods whose components are also useful in other fields like bioinformatics, parallel programming, and well-known hard optimization fields in engineering. This means a manifold advantage of the project, since optimization, net centric applications, and other important problems will receive a combined attention. Besides, this project actively seeks for transference, internationalization of results through research collaborations, and deep impact in the research with advanced methods of optimization, in the crossroad of intelligent systems, distributed environments, software, and algorithmics.

Keywords: metaheuristics, communication networks, data networks, combinatorial optimization, real world problems.

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1 Project Definition and Goals

This project defines a set of goals in the crossroad of optimization problems, data-communication networks, and the resolution of real world problems by proposing high performance techniques.

The project team is composed of four groups that have been collaborating for more than 6 years (projects TIC1999-0754-C03 and TIC2002-04498-C05) in the aim of profiting from this synergy to quickly offer in this project efficient and accurate solutions to net centric optimization problems. The team (we will use this term to refer to the complete set of researchers, in the order shown in the figure below) is made up of (9+9+13+11) 42 researchers in a joint effort to complete all the target activities.

OPLINK TEAM	OPLINK LOGO
1. **OPLINK::UMA**: University of Málaga 2. **OPLINK::UC3M**: University Carlos III of Madrid 3. **OPLINK::UEX**: University of Extremadura 4. **OPLINK::ULL**: University of La Laguna	

We aim at solving problems appearing in communication networks (GSM and ad-hoc networks) as well as using data networks for developing efficient techniques (grid computing). We also want to extend the proposals to work on additional domains in order to enhance the interest of OPLINK. In all this process we are reinforcing the training of human resources, the dissemination of results, and the creation of links to the industry as often as possible.

The scientific goals spin around the challenges proposed by the following hot topics:

- PROBLEMS: Solving problems typical in data networks, such as parallel processes scheduling, efficiency in LAN/WAN/FPGA technologies, and grid computing. Solving problems in communication networks having infrastructure, like frequency assignment to GSM networks, satellite connections, and error correcting codes, as well as in ad-hoc networks in cities, highways (vehicular networks) or metropolitan scenarios in general. Analyzing and solving the underlying optimization problems in all these applications: Hamiltonian paths in graphs, graph coloring, subset problems, etc. All this needs to be revisited for the real world applications we are tackling in the project, far from the many abstractions and simplifications usually found in the literature (here the industrial transference is very important).

- METHODOLOGY: Innovation in the techniques used, in the sense of creating advanced metaheuristics by using hybridization, parallelism, multiobjective formulation of problems and techniques, and relation to exact and ad-hoc heuristic algorithms existing in the literature.

- EXTENSIONS: Transferring techniques and knowledge to other domains like logistics, bioinformatics, economics, software engineering, and other fields of interest for the teams in this project, for the society, and for our own future research.

Table 1: Interactions of the groups in OPLINK.

Methodologies	**UMA**	**UC3M**	**UEX**	**ULL**
Metaheuristics	x	x	x	x
Exact algorithms	x			x
New algorithms	x	x	x	x
Parallelism	x		x	x
Multi-objective	x	x	x	x
Grid computing	x		x	
Software tools	x		x	
Applications	**UMA**	**UC3M**	**UEX**	**ULL**
Network environments (design, frequencies, ad-hoc, ...)	x			x
Network information theory	x	x		x
Networks (routing, parallel compilers, cryptography, ...)		x	x	
Software testing and protocol validation	x			
Web services for optimization and network environments			x	
Optimization (TSP, Knapsack, VRP, scheduling, ...)	x	x	x	x
Bioinformatics	x			x
Re-configurable software-hardware co-design			x	
2D cutting/packing	x			x
Other applications	x	x	x	x

- TRANSFERENCE: Innovation and transference to the industry, by means of actual contracts and developments with the EPOs of the project proposal. We have already done transference to OPTIMI and LUSASOFT, and started join works with SES-ASTRA and some connections with ERICSSON and Telefónica I+D.

We initially planned our interactions and complementary issues between the goals and the team in an open but concrete manner. Globally, the activity plans among the subprojects were set to foster the following ones:

1. Define a problem applicable to the industry, in collaboration with the companies associated to the project, per year.
2. Define studies to advance in the algorithmic field.
3. Study the resulting experiences to make European proposals for further work.
4. Doctoral theses co-advising among the groups.
5. Travel scheduling to disseminate the project.

We summarize in Table 1 the interactions among the groups according to the initial activities. The general statement of goals is further detailed in subsequent sections by separately discussing on technical details, chronogram, and means to achieve a (hopefully) successful project.

1.1 Technical Goals

As the technical goals we have defined three basic ones (one per year):

1. Radio Network Design (RND): optimally locate a set of base stations in order to cover a given area with a minimal cost. Usually we want a 100% of coverage meeting also a set

of constraints on the available points to install such base stations (e.g. not in museums nor in school centers). This problem is relevant to 2G/3G industry in mobile telephony, as well as it holds a close relationship to problems arising in wireless sensor networks, another field of research starting in our team.

2. Automatic Frequency Problem (AFP): optimal assignment of a reduced number of transmitting frequencies to base stations in real world GSM networks. We work in close collaboration with one company (OPTIMI) giving real examples and physical properties of the true system. Other problems like location area definition for organizing the network are of interest also. The key point with AFP is the difficulty and usefulness of the problem instances (with data coming from real GSM networks in Denver, San Diego, Seattle, and Los Angeles).

3. Mobile Ad-hoc NETworks (MANET): optimal broadcasting of messages in ad-hoc networks; in this problem the behavior of the (crucial) broadcasting protocol of the network is to be fine tuned for different scenarios like a shopping mall, streets of a city and a highway. No provider exists in MANET, and communications are carried through P2P exchanges of information. This problem is very complex, needs a study both using simulators and real systems, and shows a nice interaction with vehicular networks among cars, also a rising field demanding advanced optimization tools.

Many other problems related to these three ones are also considered, either as extensions of classical combinatorial optimization (like Steiner problems, routing in networks, location of facilities...), sensor network extensions (especially of RND), encryption algorithms for networks, and bioinformatics. In a very interesting novel approach, parts of the software can, in turn, be tested by metaheuristics, and even protocols verified for errors (another transference of impact of OPLINK).

Table 2 contains the most relevant issues; it is difficult to show a whole picture of goals, groups and years, but in this table we try to summarize the new algorithms we are developing, our target problems, the intended transfer to industry and the extensions to other fields, i.e. our four main areas of impact in OPLINK.

1.2 Chronogram

Up to now we here briefly discussed the steps and planning of OPLINK. The temporal details of the project are outlined in Table 3.

The first year has been devoted to launch the different fundamental tasks of the project, such as analyzing the real world problems to solve (RND, MANET and AFP), defining the challenges of the kind of algorithms needed (especially multiobjective and grid ones) and tests the initial extensions to other domains like economics, logistics, and bioinformatics.

The second year is being devoted to get deeper in the RND and the MANET (ad-hoc network) problems. The AFP has been formalized after real data from a company, and actual advanced algorithms are being run and characterized. In UMA and UEX two grids of computers have been created and managed (more than 300 CPUs in the two cases), by using Condor and BOINC, respectively. ProActive and Globus are also studied at present. New extensions to economy, FPGAs, and dynamic problems in MANET are being sought. We are reinforcing

Table 2: Global activities annual table.

Year	New algorithms	Network problems	Industrial transfer	Other transfers
2006	- Problem dependant - Parallel LANs - Heuristics - Cellular automata based - ACO extensions	- Ad-hoc networks - Frequency planning - Error correcting codes design - Signal processing - Optimization and cryptography - Scheduling in LANs	- Automatic frequency planning in mobile telephone networks - Defining optimization problems in satellite networks	- Bioinformatics - Logistics and VRP - Continuous numerical optimization - Finances - Research activities dissemination
2007	- Parallel multi-objective - Grid systems algorithms - Particle swarms	- Optimization and parallel compilers - Dynamic load balancing - Cluster creation in ad-hoc networks - Web services and reconf. architectures - Network routing problems	- Cryptographic processing platform - Dynamic definition of clusters in communication networks - Mobility models in mobile networks	- Medical applications - LAN task scheduling - Optimization and pre-electoral polls - Protocol validation with heuristics - Research activities dissemination
2008	- Hybrid and heterogeneous - Support vector machines	- Reliable networks design - Communication protocols validation - Parallel clusters scheduling - Network flow optimization	- Optimization in satellite communications - Reconfigurable architecture for C/S applications in the Internet - Optimization and mobility models	- Software testing - ECG interface optimization - Touristic flow optimization - Research activities dissemination

Table 3: Scientific chronogram: tasks in OPLINK by year.

Year	Scientific Tasks
2006	1. **Problems:** documentation and study of selected instances (RND, AFP, MANET plus others) 2. **Algorithms:** design of solving techniques (metaH, exact, hybrids, parallel, multiobjective); focus on ACO 3. **Industry:** Transference to OPTIMI; initiate technical contacts with other industrial partners 4. **Others:** Applications in cryptography, economics, bioinformatics, logistics, and industrial packing
2007	1. **Problems:** publish on RND, study MANET, initiate AFP; analyze routing in ad-hoc networks 2. **Algorithms:** reinforce grid computing, multiobjetive, A-teams, PSO, cellular GAs 3. **Industry:** Technical advances with SES-ASTRA; focus on cryptography, and software engineering 4. **Others:** FPGAs, economic applications, dynamic optimization in ad-hoc networks
2008	1. **Problems:** publish on RND, MANET and AFP; analyze sensor network problems 2. **Algorithms:** heterogeneous, grid versions, hybrid techniques and multiojective extensions 3. **Industry:** Reinforce results with OPTIMI, SES-ASTRA and explore ERICSSON; other potential partners 4. **Others:** applications in tourism, industrial cutting-packing, new interfaces and software testing

our collaboration with SES-ASTRA to define problems, e.g. dynamic connection from base stations to satellites in orbit.

The third year should deal with final real versions of all the problems of the project, as well as with sophisticated versions of the used algorithms (ACO, PSO, cGA, DE, A-teams...). These versions will account for the well known algorithmic branches of this project: multiobjective, grid, hybrids, and very specialized operations to improve canonical algorithms. A big effort in

dissemination will occur at this moment, and some new domains of application will be tested with the techniques explored in the preceding work of the project.

2 Degree of Success

In order to report on our degree of success at this point of the project (half in its life after 18 months of research) we can state that everything is proceeding quite well, with no negative events in the planned time schedule and scientific goals. The inertia provided by our precedent project helped us a lot to get publications from the very beginning of this project, which is a relevant detail to explain our good results.

In order to show this from a technical point of view we will include in the following sections the advances in the net centric problems of the project, the new results in designing sophisticated techniques, and the two secondary goals of creating innovation with companies and transferring techniques to other domains.

2.1 Problems

Let us start this section by summarizing the advances made in the core problems targeted in OPLINK (see Table 4). We will give the name of the problem and several brief comments on algorithms and latest advances.

Table 4: Core problems targeted at OPLINK.

Problem	Comments
RND	Solved by evolutionary algorithms (CHC, GAs, MAs) and ACO. Several publications done together, some experiments running now
AFP	Several kind of EAs already running, also BOAs, GRASP and EDAs. Experiments are in their final phase in all the groups
MANET	Multiobjective approach in all the groups: MOPSO, NSGA-II, DE, cGAs, ABySS. Writing a journal paper together
ECC	Genetic algorithms and specialized hybrids already under exploitation (several publications available)
CRYPTO	Data chypers based on IDEA and evolutionary algorithms; advances in UEX and UC3M
Others	Satellite scanning, routing in ad-hoc networks, vehicular networks, protocol validation

Let us now discuss on the scientific transference to other fields done based on the algorithms and results previously got in the core problems of this project. Table 5 briefly shows the kind of transference and several brief comments. These additional domains are selected because direct utilization of techniques created in OPLINK or because one of the groups is having additional interest in this field.

2.2 Methodology

In this section we summarize the status of the different new methodologies we are developing in OPLINK. They are initially targeted to tour applications and then extended in some way for transference to other domains and industry whenever this is possible. Table 6 summarizes such advances by showing the name of the technique, comments on its internals, and the present status at July 2007. We must remark that we are working in a coordinated manner, and most

Table 5: Transference to other domains in OPLINK.

Problem	Comments
EAs and games	Applications running in UMA, chess application finished at UEX
System identification	Work finished at UEX
Image analysis	Application to the cork industry
Fault tolerance in parallel EAs	Under development at UMA and UEX
Laser dynamics	Transference to laser industry in UEX
Biometric identification	under development at UEX
Teaching computer architecture	Relation to optimization of net centric applications, under study at UEX
Genetic programming software	Implemented at UC3M
Public market stocks	Genetic algorithms for broking assistance at UC3M
Pre-electoral enquiries	Optimal definition of voting sectors at UC3M
Encryption	GP for hash tables design and IDEA algorithms at UC3M and UEX

Table 6: Methodologies created so far at OPLINK.

Algorithm	Comment	Status
ABySS	Hybrid scatter search multibojective algorithm	Programmed and tested
Jcell	Synch-asynch cellular genetic algorithm used for bioinformatics and MANET	Programmed and tested
JMetal	Set of algorithms (GA, SS, cGA, ES...) for multiobjetive algorithms	Under experimentation
PSO	Particle swarm used for transference to bioinformatics and software testing	Under exploitation
EA	Multiple evolutionary algorithms, including greedy techniques, used for AFP	Under exploitation
CHC	Specialized GA (also multiobjective MOCHC), applied to solve RND	Under exploitation
PALS	Specialized local search for permutation based problems	Under exploitation
gridMetaH	Grid extensions: GA, CHC and cGAs for AFP, MANET and bioinformatics	Under experimentation
CLUS	Fragmentation algorithm for AFP	Programmed and tested
GRASP	Greedy randomized adaptive search procedures	Under testing
BOA	Bayesian optimization algorithm (binary encoding), used to solve AFP.	Programmed and tested
GPPE	Genetic programming projection engine	Programmed and tested
CAPM	Chromosome occurrence probability algorithm, used for RND	Under experimentation
ACO	Ant colony algorithm used for RND	Under experimentation
MA	Memetic algorithm, used for RND	Programmed and tested
MICH-PSO	Particle Swarm Optimisation, Michigan-class	Under experimentation
MOPSO	Multiobjetive Particle Swarm Optimisation, used for MANET	Programmed and tested
ES-NSGAII	NSGA adapted with evolutionary strategies, used in MANET	Programmed and tested
DE	Differential evolution used for AFP, RND and MANET	Under experimentation
PBIL	Population based incremental learning used for AFP and RND	Under exploitation
GA	Genetic algorithm used for transference (games in this case)	Under development
A-TEAM	Asynchronous set of algorithms	Under development
Grid	Grid extension of exact and metaheuristic algorithms	Under development

of the techniques are discussed and developed together in the four groups, each group leading a subset of these developments.

2.3 Others

From the point of view of industrial innovation, we have developed one year contract with the company OPTIMI, located in the Andalusian Technological Park located in Málaga. Based on previous experiences in solving GSM problems in actual networks all over the world (Harlem in Holland, Denver and Los Angeles in USA...) we have created difficult instances of AFP to later be solved in collaboration by all the groups in OPLINK. In addition, we are in contact with SES-ASTRA (Luxembourg) to define satellite problems related to OPLINK; in concrete, we expect to have initial prototypes of such problems at the end of 2007 since we already know some technical details on their definition and potential solution with the kind of techniques of OPLINK. Finally, we plan to define new problems with a new company (probably ERICSSON, but some others are receptive) related to our domains of research in this project; in particular, since the group at UMA is involved in an European Celtic project with many companies (ETRA I+D, Mobiquity, ACL, VTT...) we expect to enlarge our horizon of applications during the final year of the project (2008).

From the second point of view of our initial proposal (i.e. transference to other domains)

the near future is really promising. Large advances have been done in bioinformatics, especially in DNA fragment assembly and microarrays. Also, the techniques of OPLINK are started to be exploited in bussiness and economics with great success during the present year (2007); the same holds for industrial problems in cutting and packing (e.g. glass cutting) and for crytography. A very promising line of research is being consolidated on program testing for the industry of software, as well as on finding errors in communication protocols and other concurrent software in critical applications.

We have also been very active in developing new techniques, especially grid extensions of existing algorithms (asynchronicity, fault tolerance...) and multiobjective approaches, in which our groups are gaining a huge momentum in the international arena thanks to OPLINK. We are fostering also some specialized versions of new algorithms like ACO, PSO, differential evolution, heterogeneous techniques, and A-teams, which is also opening new lines of research for young researchers in the OPLINK team.

The effort in disseminating the project is being really hard, based on Internet web sites with technical contents, flyers announced in international conferences, seminars of the principal investigators in many countries and a very large number of visits of external researchers to our Spanish groups (more than 20 for the time being).

We can state that the level of success of our project is considerably high, making a public generation and dissemination of knowledge in different fields of high impact with the received resources from MEC.

3 Success Indicators

In this section we are including several (quantitative) means to assess the success of OPLINK. We will start by the scientific production, then the fostered collaborations and the training power of our four groups since the start of the project.

In a second part we will include the transference to industry, the coordination to deal with a large number of technical and personal issues and the dissemination of our results.

All these indicators are hopefully clarifying the relevance of the work done in OPLINK by considering the number and quality of the activities we have been performing since the start of the project, what of course are in continuous improvement until the end of it.

3.1 Scientific Production

In this section we include the figures got by our team explained in terms of high impact journals (ISI-JCR), internatinal journals not in ISI, books edited-authored, book chapters and discussions made in conferences (most of them internatinal ones).

In Table 7 the reader can find the satisfactory level of achievement of publications after running the first half of the project. Many of these publications have been made by several groups in OPLINK (for example between UMA and ULL), and most of them are a direct result of our internal meetings and problem definitions.

Table 7: Scientific production.

Sub-group	ISI Journals	Int. Journals	Books	Book chapters	Conferences
UMA	17	5	7	5	33
UC3M	11	2	-	1	13
UEX	6	2	2	1	47
ULL	1	-	-	4	21
TOTAL	**35**	**9**	**9**	**11**	**113**

Table 8: International collaborations.

Year	Type	Organization
2006	PhD theses co-direction	University of Luxembourg and UMA
2006	PhD theses co-direction	UNSL and UMA
2006	Integrated actions	UMA plus U. Leipzig and UMA plus U. Vienna
2006	INRIA mediterranean 3+3 project	UMA and INRIA
2007	Visiting fellowships	UMA and King's College (UK)
2006	Research Stay	University of Stockholm and UC3M
2006	Research Stay	Univerisity of Laval (Canada) and UC3M
2006	Lecturing and Research	University of Kyushu (Japan) and UC3M
2007	Research Stay	University of Alberta (Canada) and UC3M
2007	Lecturing	Swiss Federal Institute of Technology and UC3M
2006	Cooperation	CERN and CIEMAT-UEX
2006	One year research visit	Nagahashi Laboratory (Tokyo) and UEX
2006	PhD theses co-direction	PU of Leiria (Portugal) plus UEX and UMA
2006	Final degree project co-direction	Göttingen University of Applied Sciences (Germany) and UEX
2007	Visiting fellowships	University of EPCC (Edinburg Parallel Computing Center) and ULL

3.2 National and International Collaborations

We here summarize our most relevant collaborations; we set up a considerable effort to integrate our topics and researchers in other foreign teams in order to improve our quality and disseminate the contents of OPLINK. In Table 8 we give at a glance the developed and open collaborations.

3.3 Training and Human Resources

In the Table 9 we present the results of an intense work headed to initiate research carriers in our team and to complete the doctorate studies for the novel researchers in our groups.

Table 9: Human training.

GROUP	PhD Thesis	DEA	Master Thesis	Degree Projects	Grants and Contracts
UMA	3	2	1	10	3
UC3M	-	1	-	4	-
UEX	-	1	-	6	2
ULL	-	1	1	4	2
TOTAL	**3**	**5**	**2**	**24**	**7**

We are very active in thesis direction, either in every groups and with other partners in the world. We try to reinforce research in young engineers by involving them in simplified applications through final degree projects. Human resources is a must in our groups to improve our research, and this is why we are using all the granted resources of OPLINK to issue

contracts when possible. We are also directing several second year master theses, and most of our students are progressing for the DEA appropriately. The new system with masters in which students can finish in one year are encouraging the quick understanding of research and will hopefully allow quick integration of novel researchers in our groups.

When possible, our PhD students are demanding the European mention for their theses; this also promotes external relations in Europe since they need to spend at least three months in another country. In some cases we are having access to national FPU grants, which is an additional issue helping to get all the goals of OPLINK.

3.4 Technological Transfer to the Industry

We have started some industry transference. Some have crystalized in actual funded contracts, while others are still in the early phases of definition of goals and conditions between the companies and our team:

1. **Automatic Cell Planning: Optimization Algorithms**, UMA and OPTIMI (51.475 euros), from January to December 2006.

2. **CARLINK**, European EUREKA-CELTIC project (EU-3187, CP03-07) in which the UMA subgroup integrates with international companies like ETRA I+D, Mobiquity, VTT... to design vehicular networks. This project is funded internally by every country; in our case, through projects funded by the Spanish Ministry of Industry FIT-330210-2006-49 (57.800 euros) and FIT-330225-2007-1, from July 2006 to July 2008.

3. **Cluster Computing: Interconnection Study**, ULL and LUSASOFT (10.225,76 euros), from January 2006 to December 2007.

We are actively seeking to land our current works with SES-ASTRA, ERICSSON, Telefónica I+D, and other companies in actual contracts and knowledge transference. Some of them are likely to start running in this second half of OPLINK.

3.5 Coordination

In this project we are coordinated in the milestones for solving problems and applying techniques. For this we have had several meetings:

- February 10th 2006: starting meeting in Cáceres (Spain) to define workflow, make goals concrete and global expectations. We decide to quickly go for technical details and then a seminar on scientific issues concerning advanced techniques and net centric problems was held in Málaga on March 1st 2006.

- Additional meetings have been celebrated during 2006 by profiting from the parallel attendance of OPLINK components to international events in order to maximize dissemination and reduce costs: PPSN 2006 (Island), EVOSTAR 2006 (Hungría), MELECON 2006 (Spain), and NIDISC 2006 (Greece).

- The same idea is behind the meetings (and shared publications) hold during MAEB 2007 (Spain) and EUROCAST 2007 (Spain). Besides, members of the OPLINK team

published and met together in NIDISC 2007 (USA), LSSC 2007 (Bulgaria) and GECCO 2007 (UK).

- Technical meeting in La Laguna to define the milestones during 2007 (February 15th 2007).
- Technical meeting in Cáceres to set up the coordination of the scientific details to publish together on RND, held on May 22nd 2007.
- Technical meeting held in Madrid to advance in the technical details to work in collaboration on solving the AFP (April 20th 2007).

We have already pursued, from its conception to its publication, several articles in the 18 months of live of the project; see Table 10 for the details.

Table 10: Works made and published in a coordinated fashion.

Contents	**Groups involved**	**Status**
RND (eurocast07)	UEX, UMA	Published
RND (evocomnet07)	UEX, UMA	Published
MANET (eurocast07)	UMA, UEX, UC3M, ULL	Published
RND	UMA, UC3M, UEX, ULL	Ready to submit
MANET	UMA, UC3M, UEX, ULL	Under redaction
AFP	UMA, UC3M, UEX, ULL	Experiments running

Indeed, we are still working for more coordinated activities, like the writing of a **new Wiley book** entitled *Solving Complex Problems with Advanced Techniques*, which will hopefully appear along 2008. This book will contain much of the techniques and problems we are creating in OPLINK, as well as the most important results got in the previous project, TRACER.

A training course has been offered in UMA with attendees from all the groups. This course has been run as a formal degree of *expert by the University of Málaga* on **Metaheuristics: introduction and recent trends**, offered from March 27th to March 31st in 2006. In this line, all the four groups agreed in creating a new specialist degree at UMA on optimization and learning with metaheuristics, that will be presented as a formal course during 2007.

In the near future we have collaboration plans to offer more courses (mostly at PhD level) in other universities and countries in Europe and America (e.g. Argentina). We have also submitted a coordinated proposal to CYTED to create a new network on the fields covered in OPLINK with many countries in Latin America, that, if approved, will allow for a larger interaction among us in the next years.

In summary, we are in close contact each other and discuss frequently by email, phone and in person as often as possible.

3.6 Dissemination of Research

In order to disseminate our results we have addressed many activities in the life of OPLINK. First, we have created a flyer to publicite OPLINK in conferences (see Table 11), seminars and in visits to other groups.

Table 11: Flyer of OPLINK.

Finally, we include the **events** organized by the OPLINK team, in which many of the rest of groups have participated, either in their conception, development or final execution. Brief subsections will be used to this end.

3.6.1 UMA

1. **Session in IEEE IPDPS'06: NIDISC'06** in Rhodes (Grece), 2006
2. **Session in IEEE MELECON'06: Evolutionary Algorithms in Telecommunications** in Benalmádena (Spain), 2006
3. **Session in NM&A'06: Metaheuristics and COP** in Borovets (Bulgaria), 2006
4. **IEEE/ACM MSWIM'06** in Málaga (Spain), 2006
5. **IEEE/ACM DS-RT** in Málaga (Spain), 2006
6. **HM'06 (Hybrid Metaheuristics)** in Gran Canaria (Spain), 2006
7. **EvoCOP'07** in Valencia (Spain), 2007
8. **Session in IEEE IPDPS'07: NIDISC'07** in Long Beach (USA), 2007
9. **Session in LSSC'07: Application of Metaheuristics to Large-Scale Problems** in Sozopol (Bulgaria), 2007
10. **Symposium nb. 22 in CEDI'07: JAEM'07** in Zaragoza (Spain), 2007
11. **Session in ISDA'07: Parallel Evolutionary Computation** in Rio de Janeiro (Brazil), 2007

3.6.2 UC3M

1. **Session in CEC'06: Evolutionary Computation in Finance and Economics** in Vancouver (Canada), 2006

2. **Session in ICANN'06: Advances in Neural Network Learning Methods** in Athens (Greece), 2006

3. **Session in CEC'07: Evolutionary Computation in Finance and Economics** in Singapore, 2007

3.6.3 UEX

1. **VI Jornadas sobre Computación Reconfigurable y Aplicaciones (JCRA 2006)** in Cáceres (Spain), 2006

2. **Symposium nb. 9 in CEDI'07: JCRA'07)** in Zaragoza (Spain), 2007

3.6.4 ULL

1. **Últimos Avances en Informática** in Tenerife (Spain), 2006

2. **Últimos Avances en Informática** in Tenerife (Spain), 2007

In general the work made in OPLINK is already well known through the many sessions organized during 2006 and 2007, the publications on the topics of the project, and the flyers distributed internationally and available in Internet. All the four groups in OPLINK hold a web site with information on the internal meetings, public data files, technical reports, useful links and related information. The reader can access the individual group web sites from the main one located at UMA: `http://oplink.lcc.uma.es`.

The components of the group usually report results to other colleagues visiting us in Spain and in international events. The forthcoming book from Wiley will represent a big step in disseminating the research results of the latest years.

3.7 Other Indicators

We are collecting references made to our work by foreign groups, which is a significant indicator of the interest we are motivating with this project; for the time being they are some dozens of references, but the project is in the middle of its lifetime and cites from other researchers need some time to appear. Based on the existing sampling we think that OPLINK has a nice impact in Europe and moderately in USA and Asia (Japan and Australia specially).

Warning: only ISI journal articles included in references for space constraints

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