

<b>Acronyme</b>	<b>DOPAGE</b>		
<b>Titre du projet en français</b>	Diminution Optimale de PAramètres d'un GraphE		
<b>Titre du projet en anglais</b>	Decreasing Optimally some Parameters IN Graphs (DOPING)		
<b>CSD principale</b>	<input checked="" type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9		
<b>CSD secondaire (si interdisciplinarité)</b>	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9		
<b>Aide totale demandée</b>	60 000 €	<b>Durée du projet</b>	36 mois

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## 1. **CONTEXTE ET POSITIONNEMENT DU PROJET / CONTEXT AND POSITIONNING OF THE PROPOSAL**

Nowadays, a major industrial issue is the concept of reliability. This notion is particularly crucial in fields involving network design or management. As soon as you provide services to customers for money, you have to make sure that you will be able to fulfil your part of the contract. Therefore, you must anticipate any event that might lead you to a situation where you are unable to do so. That is, you have to be reliable.

For instance, if you must perform tasks involving some sort of network, then you are led to expect that this network does work. Designing or managing networks that do work thus appears to be essential. What sort of events could make a network break down? If the network is a telecommunication network (where each node is joined by links to other nodes, and nodes communicate with each other), some links or nodes may fail, and prevent other nodes from communicating at all. In such cases, you have to ensure that the network will still work at a certain level, which means that the failure of a single node or link must not bring the whole network to collapse. In other words, you must take this into account when designing the network (and when defining the routing policy).

Graphs are formal objects particularly relevant for modeling various kinds of real-life objects, such as networks (nodes and links becoming vertices and edges, respectively). Many problems occurring in network design can then be translated in terms of graphs, and studied with the help of powerful tools from (algorithmic) graph theory. For instance, building reliable networks can be thought of as building graphs having specific properties. A basic example is the following: a graph is said to be  $k$ -connected if the minimum number of vertices (or edges) that one has to remove in order to disconnect the graph is at least  $k$ . Moreover, in this example, we define a graph to be reliable if, after one or several failures (on vertices or edges), the remaining vertices can still communicate with each other. Therefore, if you assume that at most  $k-1$  vertices (or edges) can break down at the same time, then a network (graph) is reliable if and only if it is  $k$ -connected.

This example is a classical one, however it may happen that the right notion of reliability associated with a particular network application is a different one. As an example, assume we are given a network in which nodes (computers) have to work in pairs for a specific reason: two computers can work together only if they are joined by a link (edge), and no computer works with more than one computer. We would like to get as many pairs of computers as possible. In terms of graphs, this problem is simply a classical maximum matching problem. However, as previously, it may happen that some vertices (or edges) break down. In this case, we are interested in determining the impact of such an event on the performance of the network. If, for instance, at most  $f$  failures happen on nodes (or edges) at the same time, what is the worst value of a maximum matching in the new network? Or, to put it in terms of reliability, can we ensure that, if  $f$  failures happen simultaneously, at least a sufficient number  $p$  of pairs of computers will continue to work together? In other words, is this network reliable?

Although finding a maximum matching in a graph is an easy problem (i.e., it can be solved by efficient algorithms), it is not at all evident that the variant defined in terms of reliability is also easy. In fact, it turns out that it is not: it has recently been proved that, given a network and two integers  $f$  and  $d$ , the problem consisting of deciding whether there exists a set of  $f$  edges (links) whose removal decreases the maximum matching number by at least  $d$  units is NP-complete, and so it is very likely that it cannot be solved by efficient algorithms. However, it has also been shown that several special cases of interest are tractable.

These results constitute a first step in the study of such problems, closely related to the notion of reliability. There are other interesting examples of such problems (we shall develop them in the remaining of the project), showing that this problematic is really an emerging one. However, the systematic study and classification of these problems have not yet been initiated.

Therefore, the purpose of the current project is to start the investigations in this field of research. Since it involves a huge amount of (human and financial) resources, our ambition is only to provide a first approach to this problematic, by considering the main problems related to this topic, determining their complexity and designing efficient (exact or heuristic) algorithms to solve them, and eventually sketching a common framework to solve any problem of this type.

## **2. DESCRIPTION SCIENTIFIQUE ET TECHNIQUE / SCIENTIFIC AND TECHNICAL DESCRIPTION**

### **2.1 ÉTAT DE L'ART / BACKGROUND, STATE OF ART**

Many problems that we intend to deal with in this project have been studied only very recently. Therefore, it is not surprising that most of the references we shall mention here are posterior to 2005.

Apart from the well-known  $k$ -connectivity problem described in the presentation of the project, which has been studied for a long time [6], the first problem related to the topic of the project which we would like to mention is the partial multicut problem.

The minimum multicut problem is an NP-hard problem which generalizes the classical minimum cut problem (a very famous problem since the seminal work of Ford and Fulkerson [3]), and which has many applications: VLSI/network design, tasks assignment, etc. This problem has been extensively studied in the literature, from the point of view of both exact and approximation algorithms [2]. However, it has been pointed out later that this problem does not wholly capture some recent problems in network design. For instance, assume we are given a network (graph) and a list of  $N$  source-sink pairs of nodes (vertices), in which each source must communicate with (send messages to) the corresponding sink (as in the minimum multicut problem). Again, some links (edges) may break down, and we assume that at most  $p$  failures may happen at the same time. We would like to know whether the network is reliable, i.e., whether at least  $N-d+1$  source-sink pairs can still

communicate if these failures happen. The partial multicut problem (or  $d$ -multicut problem) then consists in determining a minimum-cardinality set of edges whose removal disconnects at least  $d$  source-sink pairs. In other words, the network is reliable if and only if the optimal value of the  $d$ -multicut problem is larger than  $p$ . This problem is a generalization of the minimum multicut problem (in which  $d=N$ ), and therefore is harder than this latter problem. However, it also models more accurately real-life problems. This is why researchers have nevertheless tried to design efficient algorithms to solve it, mostly approximation algorithms. A first paper presents algorithms for partial multicuts in tree networks [5]; a second one describes (less efficient) approximation algorithms for the general case [4]. Note that both papers have been published in 2006.

This problem is an important one, since it is related to the notion of reliability, is quite difficult (and, therefore, worth studying, both from a theoretical and applied point of view), and generalizes a major problem in graph theory and discrete optimization. Even more recently, researchers have started to study other problems which, on the one hand, do have connections with some aspects of reliability, and, on the other hand, are related to classical problems. For instance, the following problem (already mentioned in the introduction of the project) has been recently studied: given a network (graph)  $G$  with maximum matching number  $m(G)$  and two integers  $p$  and  $d$ , can we find a set  $S$  of at most  $p$  edges such that  $m(G-S) < m(G)-d+1$ , where  $m(G-S)$  is the matching number of the graph obtained from  $G$  by removing the edges in  $S$ ? (Recall that a matching of a graph  $G$  is a set of edges  $M$  of  $G$  such that any two edges in  $M$  do not share any vertices, and the matching number of  $G$  is the maximum number of edges that a matching in  $G$  can contain.) This problem is defined as the  $d$ -blocker problem. While the problem of finding a matching of maximum size in a graph is polynomial [6], it has been proved in 2008 that the  $d$ -blocker problem is NP-hard [1]. However, some meaningful special cases have been shown to be polynomial.

We cannot describe every single research work that falls into the scope of what we plan to investigate. However, the papers mentioned here show that this topic is actually trendy, although its systematic study has not started yet, and may be a hard task. This is what we intend to work on.

## **2.2 OBJECTIFS ET CARACTÈRE AMBITIEUX/NOVATEUR DU PROJET / RATIONALE HIGHLIGHTING THE ORIGINALITY AND NOVELTY OF THE PROPOSAL**

As mentioned in the introduction, the purpose of this ANR project DOPAGE is to study, for several relevant graph parameters, the best (cheapest) way to decrease this parameter. Indeed, these parameters need to be high enough in a reliable network, and we want to determine whether they do remain high enough if at most a given number of links (edges) of the network can break down at the same time.

It should be noticed that, so far, most research works led on the notion of reliability in network design considered mainly the connectivity of the graph (or the connectivity of certain parts of the graph) as the right way of measuring reliability. In other words, reliability was mainly associated with connectivity. Our purpose in this project is to explore another way of modeling network reliability: given a network (graph) and a parameter that

has to remain high in order to make the network work well enough, we want to determine how to decrease optimally this parameter in the network. This way, if we know the minimum number  $k$  of vertices or edges to remove in order to decrease this parameter by a certain (inacceptable) amount (say,  $d$  units), then, no matter how much nodes or links break down in the network (provided this number is bounded by  $k-1$ ), we can guarantee that this parameter will stay at an acceptable value (i.e., that the network is reliable). We will refer to this general class of problems as the class of reliable network design problems.

Our first objective is to determine the complexity of the most important problems in this topic, both in the general case and in the main special cases. Then, we shall study different kinds of heuristic algorithms (i.e., both approximation algorithms whose efficiency can be guaranteed a priori, and algorithms computing approximate feasible solutions, working well in practice, whose efficiency can sometimes be guaranteed a posteriori) for these problems. Ideally, these algorithms would be able to solve large classes of these problems. Finally, provided the progress of the project allows it, our last objective will consist in studying exact methods to solve them. In particular, this may also involve finding new integer/mixed-integer linear programming formulations for these problems.

The team GraphComb of the LRI laboratory, among other things, leads researches in the following topics: algorithmic complexity of graph optimization problems, robustness and stochasticity in network design. Therefore, although the skills in computational complexity and graph theory are already present in the team, studying the notion of reliability in network design is a new and interesting extension of its traditional research themes. Moreover, it is complementary to them.

The main results that we expect to achieve are the following:

- The definition of a formal framework for reliable network design, in which at least the problems given in the introduction and state-of-the-art sections must fit,
- The classification, both in terms of complexity and approximability, of the most important problems in reliable network design (that is, at least of the two problems described in the state-of-the-art section, and of their main generalizations and special cases),
- The design and validation of efficient heuristic and approximation algorithms for these problems,
- New linear programming formulations and/or valid inequalities.

The main difficulties we expect to encounter are the following:

- Since few problems in reliable network design have already been studied, determining the complexity of the remaining ones may be quite hard. Indeed, although the partial multicut problem is easily seen to be NP-hard (since it obviously generalizes a hard problem), the hardness of the  $d$ -blocker problem is not so easy to prove. The main trouble comes from the fact that we do not yet have a sufficient « pool » of NP-hard problems from which we can reduce these new problems, which is often the core element of most complexity proofs.
- Designing approximation algorithms for these problems may need to define new approximation techniques, which is often a long-term research work.

- Finally, designing new valid inequalities for these problems may also take a long time, since it needs to understand quite accurately their structure.

Apart from publications in international journals or conferences, we expect, as benefits of this ANR project, to implement and evaluate the methods designed for solving, approximately or exactly, the problems considered in this project. A great achievement would be to provide a single software, that enables a user to solve automatically and efficiently any problem that fits into the framework defined in the project, allowing this user to choose either to solve exactly or approximately the problem (depending on the time/memory resources that is/are available). The « exact methods » part might involve to use mixed-integer/integer linear programming solvers (such as CPLEX or LPSolve).

### **3. PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DU PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROJECT MANAGEMENT**

#### **3.1 PROGRAMME SCIENTIFIQUE ET STRUCTURATION DU PROJET / SCIENTIFIC PROGRAMME, SPECIFIC AIMS OF THE PROPOSAL**

As a matter of fact, the decomposition of the DOPAGE project into several tasks strongly follows the different goals we expect to achieve.

Before studying reliable network design problems from both a theoretical (complexity and approximation theory) and experimental (heuristic) point of view, we must define a formal framework (or meta-model) to be able to determine which problems actually lie in the scope of our work, that is, given any problem, does it constitute a reliable network design problem, or not? Therefore, we have:

**TASK 1. Defining a general framework in order to determine precisely the boundary of the so-called class of reliable network design problems.**

The hardest constraint is to include the main problems described in the presentation of the DOPAGE project. Once this is done, we will be interested in the complexity and (in)approximability of these problems. This involves determining general inapproximability results, as well as complexity results for the main special cases of these problems (in restricted classes of graphs or with bounded relevant parameters). This is our second task:

**TASK 2. Classifying reliable network design problems with respect to the main approximation and complexity classes.**

Then, based on these results, we shall look for efficient algorithms to solve these problems approximately in hard cases. This is our third task:

**TASK 3. Designing and validating general heuristic and approximation algorithms for reliable network design problems.**

Actually, this could be further decomposed into two tasks:

**TASK 3.1. Designing theoretically algorithms for solving reliable network design problems approximately.**

**TASK 3.2. Implementing, testing and, if possible, improving, these algorithms on full benchmarks of instances, either randomly generated or with specific structures.**

Finally, our last task will be to develop exact methods (e.g., using integer/mixed-integer linear programming) to solve reliable network design problems, using (for instance) standard solvers (such as CPLEX or LPSolve). This may involve, on the one hand, determining good (M)ILP formulations for these problems, and, on the other hand, finding new valid inequalities for these formulations, in order to improve and speed up these methods.

**TASK 4. Developing exact (M)ILP formulations to solve reliable network design problems, and, possibly, finding new valid inequalities for them.**

### **3.2 COORDINATION DU PROJET / PROJECT MANAGEMENT**

On the four participants of this ANR project, two work in Orsay, and two work at the CNAM in Paris.

Therefore, the organization we plan to use for the DOPAGE project is the following:

- The four main participants (C. Picouleau and H. Topart at the CNAM, C. Bentz and P. Dorbec at the University Paris-Sud) will start to work on Task 1 independently (and communicate by e-mails). Then, a few months after the beginning of the project, the four of us will have a meeting and share our findings. We will discuss them and find out how to unify them. Several months later, we expect to obtain what was described in Task 1.
- For Task 2, we will probably need to work all together and meet more often. We plan to take advantage of the fact that Orsay is near Paris, in order to schedule regular work sessions. These sessions will surely lead us to write draft papers. However, we will probably have to write the final versions of these papers later, once again using e-mails as a communication means.
- Task 3 will mainly be carried out in Orsay, by C. Bentz and P. Dorbec. For this task (especially Task 3.2), we plan to work with the additional help of a post-doc.
- Finally, as for Task 3, Task 4 will mainly be carried out in Orsay. The post-doc will also be involved in this task. Moreover, the possible study of new valid inequalities will also probably require working with C. Picouleau.

Moreover, at the end of the project, we will organize several work sessions in order to finish the last details of the project, and, at the very beginning of the project, there will be one or two short preliminary work sessions (in order for the four main participants to meet once or



twice all together). C. Bentz will be in charge of the actual scheduling of the work sessions (this is Task 0).

### **3.3 DESCRIPTION DES TRAVAUX PAR TÂCHE / DETAILED DESCRIPTION OF THE WORK ORGANISED BY TASKS**

We now describe in details the four tasks associated with the ANR project DOPAGE.

#### **3.3.1 TACHE 1 / TASK 1**

##### Description of Task 1:

- Person in charge: C. Bentz.
- Purpose: the definition of a general formal framework (or meta-model), in order to determine precisely what the boundary of our work must be, i.e., to determine which problems actually lie in the scope of our work, that is, given any problem, does it constitute a reliable network design problem, or not?
- Program and methods we plan to use: the starting point would be to find a first general (mixed-)integer linear programming formulation of what is a reliable network design problem. Any instance of such a general formulation would then constitute a particular reliable network design problem, and our goal will be to ensure that any reliable network design problem can be obtained by this specification process. This seems to be a promising way to start tackling this problematic. Then, we plan to use any other kind of (meta-)models to define formally the boundaries of this class of problems.
- Participants: the four main participants of the DOPAGE project will be involved in this task, first independently (working in pairs, with, on the one hand, C. Picouleau and H. Topart, and, on the other hand, C. Bentz and P. Dorbec), then together during common work sessions.

#### **3.3.2 TACHE 2 / TASK 2**

##### Description of Task 2:

- Person in charge: C. Picouleau.
- Purpose: the classification of the general reliable network design problem in terms of inapproximability, and in terms of complexity for the main special cases.
- Program and methods we plan to use: the starting point will be to study the inapproximability status of the general reliable network design problem (as described in Task 1), and the inapproximability status of the main special cases, such as, for instance, the planar case of the partial multicut problem. Then, we will identify the special cases we plan to work on in the second part of this task. This will probably include, for instance, the planar case of the d-blocker problem. Once this is done, we will work on determining the complexity status of all these special cases.

- Participants: the four main participants of the DOPAGE project will be involved in this task, during common work sessions taking place near Paris (i.e., in Paris or Orsay), taking advantage of the geographical location of the four participants.

### 3.3.3 TACHE 3 / TASK 3

#### Description of Task 3:

- Person in charge: C. Bentz.
- Purpose: the design of efficient algorithms computing approximate solutions for reliable network design problems. This refers both to approximation algorithms (with a priori guaranteed approximation ratios) and heuristic algorithms (whose performance can sometimes be guaranteed a posteriori, using any kind of bounds). The second part of this task also involves implementing these algorithms and testing them on relevant benchmarks.
- Program and methods we plan to use: the starting point will be to study the standard approximation techniques for different kinds of reliable network design problems, and try to find common ideas in them (such as, for instance, greedy methods of some sort, guided by the computation of easy parameters -such as the value of a minimum cut or the size of a maximum matching- of the graph). If this approach works, it will lead us to use these ideas to design approximation algorithms for the general network design problem. Otherwise, it will be necessary to look for new and innovating techniques (for approximation algorithms), which may take some time, or, alternatively, consider classical techniques (for heuristic algorithms), such as meta-heuristics, and find out how to adapt them to our problems. We expect to implement these methods (possibly with the help of a master student, during an internship), our ultimate goal being to actually develop an efficient tool integrating these methods, and allowing a user to automatically solve reliable network design problems approximately.
- Participants: C. Bentz (for approximation and heuristic algorithms), P. Dorbec (for heuristic algorithms) and one post-doc (in particular, for the validation and possible improvement of the algorithms in Task 3.2).

### 3.3.4 TACHE 4 / TASK 4

#### Description of Task 4:

- Person in charge: C. Bentz.
- Purpose: the design of exact algorithms for reliable network design problems. This involves finding new (mixed-)integer linear programming formulations of the general reliable network design problem, and, possibly, looking for new valid inequalities for these formulations.
- Program and methods we plan to use: the starting point will be to solve the (mixed-) integer linear programming formulation that we expect to design in Task 1 (as a first step to a general model for reliable network design problems), using standard solvers (such as CPLEX or LPSolve). Then, the next step will be to find other (good) formulations for these problems, or for large classes of these problems, and, once

again, testing them by solving them using standard solvers. Depending on the quality of these results, we may need to improve these formulations by adding valid inequalities to them. This would require to lead a theoretical study of their associated polytopes, which may be quite complicated. In any case, our final goal is to have at our disposal at least one formulation that enables us to solve these problems efficiently with the help of the right solver.

- Participants: C. Bentz, P. Dorbec and one post-doc (for the design, implementation and validation of (M)ILP formulations), but also, possibly, C. Picouleau (for working on new valid inequalities).

### 3.4 CALENDRIER DES TÂCHES, LIVRABLES ET JALONS / PLANNING OF TASKS, DELIVERABLES AND MILESTONES

Here is our planning:

Task number	Date	Title	Person in charge
1	0-6 months	Definition of a general framework	C. Bentz
2	6-18 months	Inapproximability and complexity	C. Picouleau
3	18-30 months	Heuristic and approximation algorithms	C. Bentz
4	30-36 months	Exact algorithms and MILP formulations	C. Bentz

The main technical challenges we expect to be faced with are:

- Conceptualizing the right notion of reliable network design problems, without being too specific or general,
- Finding the right problems to reduce from (in complexity proofs for reliable network design problems), that is, figuring out what are the problems whose structure is as close as possible as the structure of these problems,
- Designing new techniques for approximating reliable network design problems,
- Proving new valid inequalities for reliable network design problems, which requires to understand very accurately their structure.

The planned work sessions are the following:

- One or two work sessions three months after the beginning of the project (for Task 1), involving the four main participants,
- Four to six work sessions (one session per week during a month or a month and a half) six months after the beginning of the project (for the end of Task 1, but mostly for Task 2), also involving the four main participants,
- Then, regular (weekly) work sessions for Tasks 3 and 4 (until the end of the project), involving C. Bentz, P. Dorbec and one post-doc (and, sometimes, if necessary, C. Picouleau during Task 4).

- Finally, two or three work sessions in the last weeks of the project, involving all the participants, in order to finalize the project.

Furthermore, at the very beginning of the project, there will be one or two short preliminary work sessions, in order for the four main participants to meet once or twice all together. Then, C. Bentz will be in charge of the actual scheduling of the next work sessions (cf Task 0).

#### **4. STRATÉGIE DE VALORISATION DES RÉSULTATS ET MODE DE PROTECTION ET D'EXPLOITATION DES RÉSULTATS / DATA MANAGEMENT, DATA SHARING, INTELLECTUAL PROPERTY AND RESULTS EXPLOITATION**

In order to promote the results obtained during the project, we plan to make them available to the international community by different means. Apart from publications in international conferences and/or journals, which is a standard way of doing this, we will participate in laboratory seminars and thematic meetings (within the framework of different thematic groups, such as ROADEF or DIGITEO).

The theoretical part of our work should obviously be published in conferences and/or journals devoted to theory, but the applied (or experimental) part could also be published in specialized conferences and/or journals (such as WEA - International Workshop on Experimental Algorithms).

Moreover, we will try to promote the software designed during the project, either by making them available on our public web site, or by uploading them on web servers specialized in providing public licence (i.e., GPL) software to everyone (such as Sourceforge), or by both means. We also plan to make demos of these softwares during appropriate workshops.

#### **5. ORGANISATION DU PROJET / CONSORTIUM ORGANISATION AND DESCRIPTION**

##### **5.1 DESCRIPTION, ADÉQUATION ET COMPLÉMENTARITÉ DES PARTICIPANTS / RELEVANCE AND COMPLEMENTARITY OF THE PARTNERS WITHIN THE CONSORTIUM**

###### **Relevance of the four participants:**

- Since September 2007, Cédric Bentz is an assistant professor (« maître de conférences ») in Computer Science at the University Paris 11 in Orsay. He has received his engineer degree in 2002, and the 6-months internship he made during this last year in engineering school was about finding, testing and improving MILP formulations for solving crew assignment and rostering problems for the French national railway company (SNCF). Then, he has defended his PhD thesis in November 2006: during three years, he has worked on efficient resolution methods for graph optimization problems, and in particular for (multi)flow and (multi)cut problems. He has studied both exact polynomial-time methods (for « easy » special cases) and approximation algorithms. He has also worked on heuristic methods for

multiflow and path problems, that were tested on randomly generated instances. Recently, he has started to work, with five other researchers (including C. Picouleau), on d-blocker problems.

- Since September 2008, Paul Dorbec is a teaching and research assistant (ATER) in Computer Science at the University Paris 11 in Orsay, and in the GraphComb team of the LRI laboratory. He is a past student of the ENS Lyon engineering school, and he has defended his PhD thesis in 2007. During his thesis, he has worked on combinatorial and structural graph theory problems, but he has also been interested in designing polynomial algorithms for particular problems. His field of research is rather large, but his main research skills lie in graph theory and discrete mathematics. He is interested in working on d-blocker and partial multicut problems, and, more generally, on reliable network design problems, since it would allow him to explore combinatorial problems from discrete optimization, which is one of the main themes of his research team (GraphComb).
- Christophe Picouleau is Professor in Computer Science at the CNAM (« Conservatoire National des Arts et Métiers ») in Paris. For nearly 20 years, he has been studying the complexity and approximation status of many problems in combinatorial optimization. He has published more than fifteen journal papers in this topic. He has been interested in scheduling problems, tomography problems, and several types of graph (optimization) problems, and he has been one of the thesis advisors of several PhD students on these subjects. Therefore, his main research skills lie in complexity theory, polynomial approximation, and graph theory. His most recent research work in this particular field focuses on d-transversal and d-blocker problems, which is one of the main problems we plan to investigate in this project. He is still currently working on these problems with other researchers (in particular with D. de Werra and B. Ries from the EPFL in Lausanne).
- Hélène Topart is a PhD student at the CNAM in Paris, under the supervision of Pr Christophe Picouleau (and Pr Marie-Christine Costa). She is a past student of the ENS Cachan engineering school, and she has started her PhD thesis in 2007. The subject of her thesis is the study of several graph optimization problems, mainly from a complexity point of view, but she is also interested in designing algorithms for identifying particular classes of graphs. Before working at the CNAM, she has been a master student in Grenoble, and she has made a 6-months internship in the Computer Science laboratory in Grenoble. During this time, she has worked, under the supervision of Sylvain Gravier, on other types of combinatorial problems.

### **Complementarity of the partners:**

The main interest in working on this project with these four participants is to bring together researchers with strong skills in computational complexity and approximation theory (C. Bentz, C. Picouleau) with young researchers having a more general background in discrete mathematics (P. Dorbec, H. Topart): this will be useful, especially for Task 1, which may require to deal with different mathematical (or formal) models.

Furthermore, these four people have worked, in the past, on distinct types of problems, which may be of great help, since this project might need to work on four to five subclasses of reliable network design problems (from partial multicut to d-blockers). C. Bentz has mainly worked on (multi)cut problems, C. Picouleau (among other things) has worked a lot

on tomography, as well as d-transversal and d-blocker problems, P. Dorbec has worked on several notions related to domination in graphs (which is another concept of interest in network design), and H. Topart has worked on recognition problems in graphs (another way of looking at our problems is, for instance, to ask whether a particular network belongs to the class of reliable networks, and so this approach can be complementary).

Finally, it seems useful that, on the one hand, some of the participants of this ANR project are capable on (and are particularly skilled at) working on purely theoretical problematics (complexity or (in)approximability status of a given problem), and that, on the other hand, some others are also capable on working on a more experimental way of solving and studying problems (designing and testing heuristics, designing and testing MILP formulations, etc.), and may have the opportunity to build bridges between these two important topics. Indeed, both aspects seem to us of equal interest, and, as a consequence, both should be considered equally.

## **5.2 QUALIFICATION DU PORTEUR DU PROJET / QUALIFICATION OF THE PRINCIPAL INVESTIGATOR**

Cédric Bentz is a young researcher, that has already proved his ability to work on hot research topics, alone or with several other researchers. He has published twelve papers in international journals (four on his own, eight with various co-authors) since 2003, the beginning of his research career. He already worked with C. Picouleau on several occasions when he was at the CNAM in Paris, and their collaborations (sometimes with other researchers) led to significant results.

Moreover, he has been involved in several tasks: he has been an elected member of the laboratory council at the CNAM when he has a PhD student, and has been the webmaster of the OC team of the CEDRIC laboratory at that time. Now, he is webmaster of the GraphComb team of the LRI, and co-organizer of the seminar of this team. Therefore, he is used to having responsibilities and initiatives.

Finally, he has made a 6-months internship at the research and technology direction (DRT) of the SNCF company in 2002. During this period, he has worked on an industrial project, meant to improve the management of train crews. Therefore, he has learned how to deal with the daily constraints (both time and resources constraints) of such a project, and how to work with people having skills complementary to his own.

For all these reasons, he undoubtedly seems to be able to play the role of the person in charge of this ANR project DOPAGE.

### 5.3 QUALIFICATION, RÔLE ET IMPLICATION DES PARTICIPANTS / CONTRIBUTION AND QUALIFICATION OF EACH PROJECT PARTICIPANT

	Nom	Prénom	Emploi actuel	Unité de rattachement et Lieu	Discipline*	Personne. mois	Rôle/Responsabilité dans le projet 4 lignes max
Coordinateur	BENTZ	Cédric	MCF	Université Paris-Sud et LRI (Orsay)		30	Etude de la complexité et de l'inapproximabilité des problèmes, conception d'heuristiques, modélisation par la PLNE
	DORBEC	Paul	ATER	Université Paris-Sud et LRI (Orsay)		12	Etude de la complexité et de l'inapproximabilité des problèmes, conception d'algorithmes approchés et de méthodes exactes
	PICOULEAU	Christophe	PU	CNAM et laboratoire CEDRIC (Paris)		24	Etude de la complexité et de l'inapproximabilité des problèmes, recherche d'inégalités valides
	TOPART	Hélène	doctorante	CNAM et laboratoire CEDRIC (Paris)		6	Etude de la complexité et de l'inapproximabilité des problèmes

## 6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDÉS / SCIENTIFIC JUSTIFICATION OF REQUESTED BUDGET

### 1. Équipement / Equipment

None.

### 2. Personnel / Staff

We need a one-year post-doc for Tasks 3.2 and 4.

### 3. Prestation de service externe / Subcontracting

None.

### 4. Missions / Missions

We expect the four participants to attend between eight and twelve international conferences or workshops during these three years, in order to present the results obtained in this project (for instance, WG, ICALP, ESA, STACS...)

## *5. Dépenses justifiées sur une procédure de facturation interne / Internal expenses*

None.

## *6. Autres dépenses de fonctionnement / Other expenses*

We need one desktop computer for the post-doc.

## **7. ANNEXES**

### **7.1 RÉFÉRENCES BIBLIOGRAPHIQUES / REFERENCES**

- [1] C. Bentz, M.-C. Costa, D. de Werra, C. Picouleau, B. Ries and R. Zenklusen. Blockers and Transversals. To appear in Discrete Mathematics (2008).
- [2] M.-C. Costa, L. Létocart and F. Roupin. Minimal multicut and maximal integer multiflow: A survey. Euro. J. of Oper. Res. 162 (2005) 55-69.
- [3] L.R. Ford and D.R. Fulkerson. Maximal Flow Through a Network. Canadian Journal of Mathematics 8 (1956) 339-404.
- [4] D. Golovin, V. Nagarajan and M. Singh. Approximating the k-multicut problem. Proceedings SODA (2006) 621-630.
- [5] A. Levin and D. Segev. Partial multicuts in trees. Theoret. Comp. Sc. 369 (2006) 384-395.
- [6] A. Schrijver. Combinatorial Optimization - Polyhedra and Efficiency. Algorithms and Combinatorics 24 (2003). Springer.

### **7.2 BIOGRAPHIES / CV, RESUME**

**Cédric BENTZ :**

28 ans, Maître de conférences à l'Université Paris-Sud (Orsay) depuis septembre 2007

#### Déroulement de carrière :

- depuis septembre 2007 : Maître de conférences – Université Paris-Sud
- 2006-2007 : ATER - Conservatoire National des Arts et Métiers
- 2003-2006 : Allocataire-moniteur - Conservatoire National des Arts et Métiers
- Janvier à juin 2002 : Stagiaire (stage ingénieur R&D) à la direction de la recherche et de la technologie (DRT) de la SNCF

#### Cursus :

- 2003-2006 : Doctorant en informatique du CNAM (thèse soutenue en 2006)
- 2003 : DEA Informatique et Recherche Opérationnelle (IRO) à l'Université Paris 6 (mention Très Bien)
- 2002 : Diplôme d'ingénieur en informatique de l'IIIE (devenue ENSIIE depuis 2006)
- 1997-1999 : CPGE à Paris
- 1997 : Baccalauréat S au lycée Lakanal (Sceaux)



Publications significatives récentes (12 publications en revues au total depuis 2003) :

- C. Bentz, M.-C. Costa, N. Derhy et F. Roupin. Cardinality constrained and multicriteria (multi)cut problems. A paraître dans J. of Discrete Algorithms (2008).
- C. Bentz, M.-C. Costa, D. de Werra, C. Picouleau et B. Ries. On a graph coloring problem arising from discrete tomography. Networks 51 (2008) 256-267.
- C. Bentz. On the complexity of the multicut problem in bounded tree-width graphs and digraphs. Discrete Applied Mathematics 156 (2008) 1908-1917.
- C. Bentz. The maximum integer multiterminal. Operations Research Letters 35 (2007) 195-200.
- C. Bentz, M.-C. Costa et F. Roupin. Maximum integer multiflow and minimum multicut problems in two-sided uniform grid graphs. J. of Discrete Algorithms 5 (2007) 36-54.

**Paul DORBEC :**

28 ans, ATER à l'Université Paris-Sud (Orsay) depuis septembre 2008

Déroulement de carrière :

- depuis septembre 2008 : ATER – Université Paris-Sud
- Janvier-Août 2008 : Visite postdoctorale de 8 mois au Mathematics Institute, à Oxford (Royaume Uni)
- 2005-08 : Allocataire-moniteur à l'Université Joseph Fourier (Grenoble 1)
- Février-Juillet 2006 : Séjour de 6 mois à l'université du KwaZulu Natal, Pietermaritzburg (Afrique du Sud), financé par une bourse de mobilité régionale (ExploraDoc)
- 2001-05 : Elève-professeur à l'ENS de Lyon

Cursus :

- 2004-07 : Doctorant en mathématiques-informatique à l'Université Joseph Fourier (Grenoble 1), sous la tutelle de Sylvain Gravier (thèse soutenue en 2007)
- 2003-04 : Master 2 de Recherche Opérationnelle et Combinatoire à l'ENSIMAG
- 2002-03 : Maîtrise à l'ENS Lyon
- 2001-02 : Licence à l'ENS Lyon
- 2001-04 : Magistère d'Informatique et Modélisation à l'ENS Lyon
- 2001 : Admission à l'ENS Lyon, section Informatique

Publications significatives récentes (12 publications en revues au total) :

- P. Dorbec et S. Gravier. Paired-domination in P5-free graphs. A paraître dans Graphs and combinatorics (2008).
- P. Dorbec et M. Mollard. Perfect Codes in Cartesian Products of 2-Paths and Infinite Paths. Electron. J. Combin. 12 (2005), #R65.
- P. Dorbec, M.A. Henning et D.F. Rall. On the upper total domination number of Cartesian products of graphs. J. Combinatorial Optimization 16 (1) (2008) 68-80.
- P. Dorbec, S. Klavžar, M. Mollard et S. Špacapan. Power domination in product graphs. SIAM J. Disc. Math. 22 (2) (2008) 554-567.
- P. Dorbec, S. Gravier et G. Sárközy. Monochromatic Hamiltonian t-tight Berge-cycle in hypergraphs. J. of Graph Theory 59 (2008) 34-44.

Distinctions :

- 1998 : Mention régionale au concours général de mathématiques

**Christophe PICOULEAU :**

42 ans, Professeur des Universités 2ème classe au CNAM (Paris)

Déroulement de carrière :

- 01/09/2003 : Professeur des Universités - Conservatoire National des Arts et Métiers
- 01/10/1994 : Maître de conférences - Conservatoire National des Arts et Métiers
- 01/10/1992 : ATER - Université Paris 6

Titres universitaires :

- 2000 : Habilitation à Diriger les Recherches, Université Paris 6
- 1992 : Doctorat de l'Université Paris 6
- 1989 : DEA d'Informatique de l'Université Paris 6

Publications significatives récentes (18 publications en revues au total) :

- M.-C. Costa, D. de Werra, C. Picouleau et B. Ries. Bicolored matchings in some classes of graphs. *Graphs and Combinatorics* 23 (2007) 47-60. Addendum, *Graphs and Combinatorics* 24 (2008) 127-128.
- C. Bentz, M.-C. Costa, D. de Werra, C. Picouleau, B. Ries et R. Zenklusen. Blockers and Transversals. To appear in *Discrete Mathematics* (2008).
- M.-C. Costa, D. de Werra, C. Picouleau et B. Ries. On the use of graphs in discrete tomography. *4OR* 6 2 (2008) 101-123.
- M.-C. Costa, F. Jarray et C. Picouleau. Complexity results for the horizontal bar packing problem. *Inform. Proc. Let.* 108 6 (2008) 356-359.
- S. Brocchi, A. Frosini et C. Picouleau. Reconstruction of binary matrices under fixed size neighborhood constraints. *Theoretical Computer Science* 406 (2008) 43-54.

**Hélène TOPART :**

26 ans, doctorante en informatique au CNAM (Paris) depuis septembre 2007

Cursus :

- 2006-2007, Master 2 ROCO (Recherche opérationnelle et combinatoire) à l'UJF, Grenoble, mention très bien.
- 2005-2006, agrégation de mathématiques, option informatique, reçue 62ème.
- 2004-2005, Maîtrise de mathématiques, Université Rennes 1, mention bien, admise 7ème à l'ENS Cachan (concours 3ème année).
- 2003-2004, Licence de mathématiques, Université Rennes 1, mention très bien.
- 2000-2003, CPGE (MPSI, MP\*), lycée Henri Wallon, Valenciennes.

Publications :

- Frédéric Cérou, Pierre Del Moral, François Le Gland, Arnaud Guyader, Pascal Lezaud et Hélène Topart. Some recent improvements to importance splitting. Proceedings of the 6th International Workshop on Rare Event Simulation, Bamberg, October 9-10, 2006.

**7.3 IMPLICATION DES PERSONNES DANS D'AUTRES CONTRATS / INVOLVEMENT OF PROJECT PARTICIPANTS TO OTHER GRANTS, CONTRACTS, ETC...**

No project participant is currently involved in other projects.