Action de Recherche Amont

SECURITE, SYSTEMES EMBARQUES ET INTELLIGENCE AMBIANTE

Scientific Description of the project

SOGEA

Security **O**f **G**ames. **E**quilibria and distributed **A**lgorithms.

Key words: security, stability, algorithmic game theory, distributed algorithms, complexity, approximation, self-stabilization, inter-domain routing, sensor networks.

Abstract

Classical distributed algorithms have been mostly conceived under the hypothesis that each involved partner has no incentive in doing something different from what it is expected to do, without taking into account the possible economical interests of each partner.

This may be the source of serious security problems. Indeed, to guarantee for example the security of a protocol for telecommunication networks, or the security of a sensor-driven database, one must be able to guarantee that the presence of one or few adverse partners, could not lead to serious situations, or completely deteriorate the performances of the whole network. This becomes more and more crucial, as the size of the networks is increasing, or as the number of economical partners involved in today's networks is increasing.

Mathematical game theory studies the equilibria reached by rational players in competition, and Mechanism theory the possible games which may lead to equilibria. In recent years, algorithmic versions of these theories have been developed to study efficient methods to compute or verify approximate equilibria.

Algorithms from distributed algorithm theory must be reconsidered under these points of view, in order to guarantee their correct behavior and performances even in presence of partners with divergent economical interests, or that could be subject to some selfish behaviors.

Our common long-term objective is to contribute to understand algorithmic game theory and its applications to classical and self-stabilizing distributed algorithms, in particular the notions of stability in this context. We wish to provide sufficient conditions which guarantee some stability and study the dynamical aspects by analytic methods whose complexity is well understood; and more generally, to understand trade-off between efficient algorithms and analyzable algorithms in this concept.

By this action, we propose specifically the following points:

- produce some notions of stability adapted to problems related to security of distributed systems;
- produce some distributed algorithms, preferably self-stabilizing, for simple models coming from problems related to inter-domain routing in telecommunication networks, and sensor-driven databases with guarantees of security in terms of these notions of stability;
- the proposed solutions will be validated analytically and by simulation.

1 Goal and context

Partie à rédiger en Anglais.
On précisera, en particulier, les verrous scientifiques et technologiques à dépasser, l'état de l'art ainsi que les projets concurrents ou similaires connus dans le contexte national et international, en particulier ceux auxquels les équipes du projet participent.

1.1 Distributed Systems and Security

The today development of heterogeneous communication networks, dealing with telecommunications, sensor-driven databases and ambient intelligence (see for example the call "Situated and Autonomic Communications (COMS)" of the FET of the 6th IST) has promoted the study of heterogeneous and dynamic distributed systems. As a consequence, there is a crucial need for robust distributed algorithms to allow and control the different interactions between senders, that may be selfish actors or equipments. To guarantee the robustness of algorithms, performances are often evaluated in a worst case basis, in ways that tolerate that some agents or some parts of the systems are faulty, or even that some agents are Byzantine, or enemies: see *e.g.* [Lyn97].

More recently, some algorithms have even been improved to be self-stabilizing: see *e.g.* [Dij74, Dol00]. Independently of the initial state of the system, in a finite time, the system is guaranteed to come back to a correct behavior. This means, that even if an unexpected event happens, they are guaranteed to come back to a correct behavior after some time. However, in the conception and in the analysis of all these algorithms, the following hypothesis is classically made: each (non-faulty, non-enemy) agent involved in the algorithm behaves has it is supposed to, in the social interest of the whole community. This is not compatible with the fact that the policies of all the actors of a communication networks are private and different, even if they share a common point-to-point communication protocol.

Thus, considering that most partners involved in today's protocols or today's distributed systems could have different (may be opposite) economic interests, we must take into account that agents may have some profits in behaving differently.

To avoid serious security problems not covered by classical analysis of algorithms, we must be able to guarantee that the presence of one or few non fully altruist partners in a protocol or in a distributed system could not lead to serious situations, or could completely deteriorate the performances of the whole system.

We believe this becomes more and more crucial, as the sizes of the distributed systems are increasing, or as the numbers of economical actors involved in today's communication networks or distributed systems are increasing.

We would also state that, even if we are focusing above on security aspects, understanding fully all the economic aspects in distributed systems brings new very interesting questions, challenges, and methods, whose use in the conception of future systems could really help.

We would like to illustrate this by two simple concrete examples.

1.2 Example 1: Inter-Domain Routing

Distributed algorithms for routing do not take into accounts the economic interests of involved partners: see *e.g.* [Lyn97]. Let us take the case of inter-domain routing in Internet. Basically, routing between different domains belonging to different operators is done following business relationships according to the BGP protocol (Border Gateway Protocol). Regardless from particular preferences and transit restrictions, the BGP protocol routes the traffic on the shortest paths in term of hops and thus costs are not incurred.

With these assumptions, a simple version of the protocol can be abstracted by the following distributed algorithm (a kind of distributed Belmann-Ford algorithm [Bel58, FF62, CLR90]):

- each node of the network (Autonomous System in the terminology of inter-domain routing), queries its neighbors whether they know a path to reach each expected destination, and if so, ask them to return the corresponding length.

- After receiving the informations from all its neighbors, each node updates his routing table in order to route each packet towards some destination to the (or one of the) neighbor(s) that claim(s) to know the shortest path to this destination.
- And so on repeatedly in each node, until the routing tables stabilize.

This algorithm computes routing tables in a distributed manner where the selected paths are the shortest one in terms of number of hops.

Now, let us consider a more realistic model, as considered by some partners involved in this project [BBEV05] where costs are incurred in routing decisions and thus economic issues are involved. In this proposition, each autonomous system that has its own routing policies is considered as an independent commercial partner. The different business relationships that exist are abstracted as follows: Each autonomous system receives some profit when handling transit traffic from an other autonomous system. Conversely, it has to pay for the transit traffic that he sends to its neighbors.

Situations can arise where an autonomous system has an incentive to lie about shortest paths in order to attract transit traffic and thus increase its profits. How can we then guarantee that no commercial partner is modifying the implementation of the protocol in order to serve its own interests? This is clearly a question related to security.

Now, another fundamental question can be of interest: How commercial partners should fix their prices for the transit traffic that use their domain? This is a question closely tight to the conception of the distributed system itself. No classical algorithmic seems to help here.

Suppose that the prices are fixed iteratively in a distributed way by the different economic partners. Such mechanism can stabilize on a situation where each partner is satisfied with its costs (incurred by the computed prices). Now, experimental simulations show that for some pricing policies the network stabilize when for other it does not, whereas we have no clear explanation of the reason behind such behaviors. One point of interest is then to understand tools that can be used to investigate the dynamic of such models.

1.3 Example 2: Security of Sensor-driven Databases

A sensor is a “small” device that produces a measurable response to a change in a physical condition such as temperature or in a chemical condition such as concentration. The sensors have wireless communications devices attached to them, and if deployed near to each other, they will network themselves automatically. These sensors, which would cost pennies each if mass-produced, could be dispatched or deployed all over some area to be monitored. Taken together, all sensors would constitute a huge sensor network of “smart dust”, a network that would give control insight into how parameters are evolving and how they can be conserved. Essentially, smart dust is made up of thousands of sand-grain-sized sensors that can measure several key parameters.

Note that sensor networks are application driven and concern specific networks of wireless nodes that sense/monitor certain phenomena of interest and report. We can distinguish here the continuous monitoring versus event-triggered monitoring. As usual, one can found a lot of military applications, another facet of “security” oriented applications as: Surveillance of sensitive areas, personnel monitoring, target detection, intrusion detection... but also civilian applications that deal also with security like: Forest fire detection, habitat monitoring, smart homes...

To properly exploit the huge amount of data that is likely to be collected by a sensor network, dedicated databases are needed. One typical example is when the central database must maintain some global functions of all measurements of sensor network, such as *frequency moments*. Frequency moments of a data set represent interesting demographic information about the data, and are important features in the context of database applications. In particular they indicate the distinct values for an attribute in a relation, and the skew of the data. The space complexity of computing these moments, as well as this application, is studied *e.g.* in [AMS96].

However, current studies lack exploring commercial tradeoff in the design of sensor networks (*e.g.* for a specific application such as intrusion detection, how many sensors located in which area would permit sufficiently good detection at an acceptable price?), as well as safety insurance when the sensor network is deployed in a "hostile" area (*e.g.* if some sensors are tampered with of modified by an enemy/competitor of the sensor network owner, how reliable are the measurements, and how long will the sensor network be useful ?).

1.4 Algorithmic Game Theory

Game theory is a branch of mathematics that aims at predicting toward which situation(s) converges a set of rational partners in a situation of competition, such as an economic competition [OR94].

In particular, a Nash Equilibrium [Nas50] is a configuration in which no rational partner has some unilateral incentive to depart: if the choices (called strategies in this theory) made by its opponents are kept fixed, it has no benefits in changing unilaterally his own strategy.

Nash equilibria correspond to stable situations: indeed, in any other situation, one of the partners has some reason to change its strategy, and hence the system has some reasons to evolve.

The field of mechanism design, sometimes called implementation theory, is a branch of game theory that aims at providing methods to guarantee that the Nash equilibria of a system do belong to a given desired subset of configurations. For example, it provides mechanisms to conceive auctions that guarantee that no rational bidder has some interest in not being truthful on its evaluation of presented items. Famous game theorists have indeed been involved in auctions for the spectrum allocation problem in America [McM94].

Most developments of these theories have been done before recent developments of today's computer science, and in particular without true considerations of effectiveness or of complexity of proposed solutions. For example, whereas the theorem of Nash in [Nas50] says that there always exists at least one (mixed) Nash Equilibrium, this is practically not so useful if there is no way to compute some strategies that lead to such an equilibrium.

These concerns have recently motivated a whole series of research papers devoted to understand which of the constructions from game theory and mechanism design are effective and which are not. Efficient methods to compute or verify approximate equilibria have also been devised. This leads to what is now called Algorithmic Game Theory.

1.5 Related projects

Some members of this project are involved in other projects, but not directly on algorithmic game theory, and its relations to distributed algorithms. Some particular projects we are involved in are listed at the end of this document, and in the requested administrative document submitted with this project.

The remaining of this section describes related projects at the worldwide level.

Algorithmic Game Theory. Several projects related to algorithmic game theory have emerged in the last few years. Among them, the group P2PECON at Berkeley focus on economics-informed design of peer-to-peer, ad-hoc and overlay networks. The EconCS Group from Harvard is pursuing research, both theoretical and experimental, at the interface between computer science and economics. In particular, their topics of interest include the design of mechanism infrastructures for distributed and peer-to-peer systems. The Computational Economics Group of the Hebrew University of Jerusalem also works on mathematical foundations for automated trades on the Internet, design of algorithms that behave optimally even when they involve selfish participants or protocols to operate within complex trading environments.

At the European level, the DELIS (*http://delis.upb.de/*) project has several themes that are close to those described in this project. In particular, they study algorithmic game theory and its applications to computer networks. To our knowledge, no French computer scientist or mathematician is involved in this European project.

Inter-domain Routing. Many international projects focus on the Quality of Service (QoS) management in a dynamic and heterogeneous inter-domain networks. The European project MESCAL (and its continuation with project AGRAVE) has studied some distributed solutions to guarantee QoS in a BGP networks.

The NSF project "Beyond BGP" focus on the dynamic and heterogeneous aspects of a BGP networks and the IST European project INTERMOM investigates some first links between economics and selfish behaviours in a BGP networks. In the network of excellence EURONGI on the next generation of Internet, the Specific Project AUCTION (in which PRiSM is involved) focus on the use of auctions to manage the economic relations between autonomous systems. From another point of view the European project DELIS, and in particular the subproject "Game Theoretic and Organizational Economics Inspired Approaches", focuses on the way of understanding and controlling complex and heterogeneous systems. Our project on the relations between algorithmic game theory and distributed algorithms could so be a major key-point from all these projects point of view.

Sensor Networks. There exist numerous international projects. We only list here two in the US and one in Europe.

At the international level, the research program in Networking Technology and Systems (NeTS) of the National Science Foundation (NSF) has launched an ambitious program to sustain the science and technology needed to fulfill our vision for next-generation networks. This program solicitation seeks innovative, forward-looking research projects in networking research broadly defined and in the focus area of *Networking of Sensor Systems*.

The NEST project is developing an Open Experimental software/hardware Platform for Network Embedded Systems Technology research that will accelerate the development of algorithms, services, and their composition into challenging applications dramatically. Small, networked sensor/effector nodes are developed to ground algorithmic work in the reality of working with numerous, highly constrained devices.

The National Centers of Competence in Research (NCCRs) are placed under the authority of the Swiss National Science Foundation (SNSF) to promote long term research projects in areas of vital strategic importance for the evolution of science in Switzerland, for the country's economy and for Swiss society. The TERMINODES project's goal is to study fundamental and applied questions raised by new generation mobile communication and information services, based on self-organization. Such systems have become very topical lately with the advent of *ad hoc* mobile networks and Peer to Peer services on the Internet. Yet, many of the fundamental questions remain to be solved, and applications are often only emerging now.

2 Project description

Partie à rédiger en Anglais sur 5 à 10 pages.
Entre autres, le caractère innovant du projet (concepts, technologies, expériences ...) devra être explicité et la valeur ajoutée des coopérations entre les différentes équipes sera discutée.

2.1 Objectives

The objective of this project is to contribute to algorithmic game theory, and its applications to, possibly self-stabilizing, distributed algorithms. In particular, our aim is to contribute to understand the notions of stability in this context, and methods for guaranteeing stability.

We aim at providing possibly self-stabilizing algorithms guaranteed to be safe, through methods whose complexity is well understood.

We propose to base our work on simple abstract models taken from the two chosen domains of applications mentioned in previous section: inter-domain routing in telecommunication networks, and problems related to sensor-driven databases.

This can be summarized as follows:

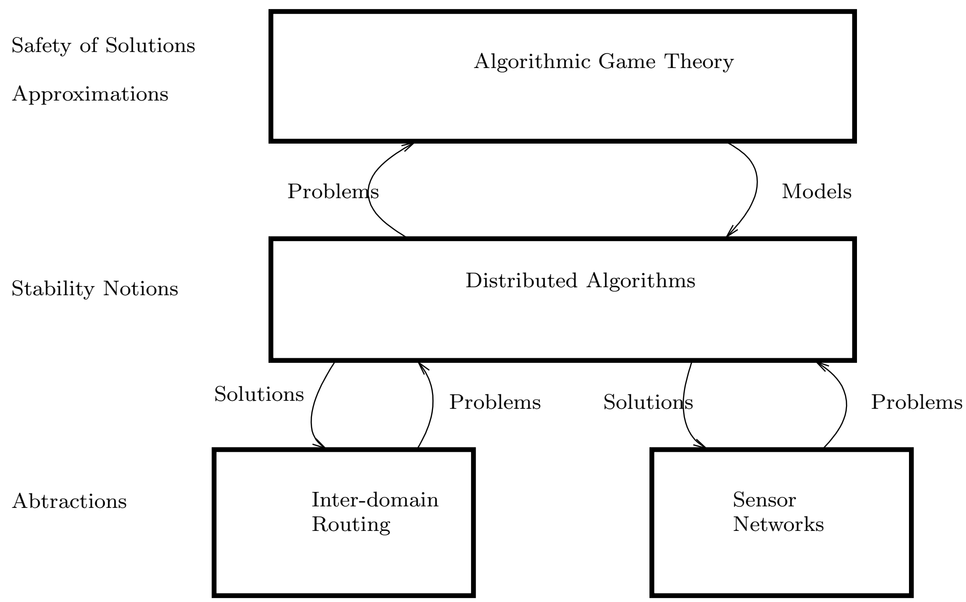

Figure 1: Schematic view of the project

At lower level, we have problems coming from the two fields of applications: inter-domain routing, and sensor networks. This level implies questions of modelization to provide tractable realistic abstractions.

Provided solutions will be based on distributed algorithms, which constitute the middle level of our schema. Self-stabilizing algorithms will always be researched, whenever possible.

The correctness and the safety of these distributed algorithms will be provided by arguments coming from the higher level, *i.e.* models from algorithmic game theory.

Proposed solutions will have a well-understood complexity. When no exact or efficient solution can or will be found, formally proved approximations will be considered. The provided solutions will be validated analytically and by simulation.

2.2 Involved Participants

Participants involved in this project come from various horizons: algorithmic for telecommunication networks, computability and complexity theory, and self-stabilizing distributed algorithmic.

This is globally explained by the distinct levels of expertise required by Figure 1.

More specifically, several people come from the algorithmic for telecommunication fields. Indeed, as we argued in previous section, the conception of safe protocols for telecommunication networks, such as inter-domain routing, directly rise to questions related to algorithmic game theory, and pricing problems. Several people involved in this project are involved with industrial partners in projects related to pricing of services in telecommunication networks.

Several people come from the complexity point of view. Up to this date, algorithmic game theory has received most of its attention in this community.

Indeed, models of economic inspiration do provide new original distributed computational models, that seem to differ greatly from more classical parallel models (see *e.g.* [BDG88]), or more recent models such as bio-inspired, or quantum models. As observed in [Pap01], as the size of the Internet is increasing, these models are more and more realistic models of what can be computed by today's networks.

Observe that, as Nash equilibria of a system can be seen as the local minima of some function [MM96], a system of agents in competition can be also considered as a natural distributed computational model, mixing discrete and continuous aspects [Bou99], implementing naturally operators like finding zero or finding local minima of functions [BH04b, BH05].

Several other people involved in this project come from the self-stabilization community. They are also involved in projects related to sensor-driven databases. Since Nash equilibria correspond to some notions of stability that share several aspects with notions considered in self-stabilization, the need for their expertise is clear. Furthermore, from the algorithmic point of view, as we will discuss, techniques to be able to discuss the dynamics of competitive systems are really missing, and we think that methods from self-stabilization could provide solutions.

If the participants come from distinct horizons, they have already all met. Each participant has already co-authored a paper or is currently working with at least another participant.

The collaboration will be a really new one as a whole. Furthermore, we think that a strength of this project is that we share same long-term objectives:

- contribute to understand algorithmic game theory and its applications to classical (and possibly self-stabilizing) distributed algorithms, by analytic methods whose complexity is well understood;
- understand notions of stability adapted to distributed algorithmic, and corresponding proof techniques.
- understand the methods that allow to discuss dynamical aspects;

and more generally, understand trade-offs between efficient algorithms and analyzable algorithms in this concept.

Exchanges between participants will be guaranteed by (at least) bi-annual workshops involving all participants, with presentations off ongoing works on federative topics.

2.3 Algorithmic Game Theory & Mechanism Design

We now provide a brief state of the art, concerning algorithmic game theory and mechanism design.

There has been an important number of papers in the last few years devoted to these subjects. We only mention here a few of them, mostly those related to our applications.

Some researchers started to study the introduction of taxes and contract mechanisms in protocols or in distributed algorithms, to guarantee that every rational agent has no incentive in departing from what it is expected to do for the social welfare of the whole group.

Constructions based on Vickrey-Groves-Clarke mechanisms [Vic61, Gro73, Cla71] have been proposed for several problems such as task scheduling, or minimal spanning tree computations in [NR99].

Vickrey-Groves-Clarke mechanisms work very well when the social function to optimize is a linear combination of the utility of each participants. Conceiving mechanisms when this hypothesis is not met is not so easy. Attempts to escape from these limitations exist [DV04]. Notice that proposed solutions may also suffer from other robustness problems, such as unbounded taxes.

Computational Feasible Versions of Vickrey-Groves-Clarke mechanisms have been discussed: see *e.g.* [NR00]. The distributed computation of Vickrey-Groves-Clarke prices has been investigated. For example, it has been proved that a distributed pricing mechanism can be added to BGP in order to guarantee that Nash equilibria correspond to states that minimize some social cost over the global network [FPSS02].

Still in the field of mechanism design for networks, methods for handling congestions in networks have been proposed in [GJS04]: the messages to be deleted in the queues of each router, when they saturate, are chosen preferably among the partners that do not respect their contract.

Some techniques for evaluating partners, and dealing preferably with good ones, have been proposed in peer-to-peer networks [NWD03a, NWD03b].

There has been a whole series of papers devoted to the question of the pricing of services in networks. For example, the question on how to fix prices in a fair manner in a multicast has been discussed in [FPS01, FKSS03, FKSS01].

A whole series of papers has been focusing on the question of bounding or computing the price of anarchy or the price of stability, for distributed algorithms, introduced respectively [Pap01] and [ADTW03, CSM04]. See *e.g.* [FGL$^+$03, Czu03] for surveys with numerous references on the subject.

2.4 Stability Aspects

We think that extensions of the previous results to more general models are needed.

For example, in our sensor-driven database application, we need to consider models with economic constraints, but also with possibly enemy agents. The question on how to mix the notion of economic agent from game theory, with the notion of adversary from classical distributed algorithms need to be addressed.

We think this is deeply related to a global discussion on the notion of stability in the context of distributed algorithms. Indeed, when limited to this latter context, since adversaries are classically considered in a worst case basis, notions of stability for distributed algorithms (for *e.g.* in auto-stabilization literature) are very different from the notions of game theory.

In a symmetric way, in pure game theory, it has often been observed that the notion of Nash equilibria is a very weak notion, and often rather unrealistic [OR94], and hence, to avoid these problems, numerous variants have been proposed in literature (perfect equilibria [Sel75], proper equilibria [Mye78], sequential equilibria [KW82], stable equilibria [Nas50] ...etc): see *e.g.* [vD87].

In a context like inter-domain routing, the researched notion is related to a stability in terms of routing tables. This corresponds to some notion of stability or equilibrium that still differs by some aspects.

In this project, we plan to contribute to the following aspects:

- Design formally well understood notions of stability that encompass the two main application domains that we considered (inter-domain routing and sensor networks);
  - Concerning applications to inter-domain routing, this requires to complete and expand the model from [BBEV05].
  - Concerning applications to sensor networks, this requires to propose notions of stability that encompass notions from game theory and from classical distributed algorithmic.
- Provide extensions of mechanism design techniques able to deal with these proposed notions of stability. Our purpose is to provide mechanisms, or sufficient conditions to derive mechanisms, that provide guarantees in terms of the proposed notions of stability.

2.5 Dynamical Aspects

Game theory predicts toward which situation(s) a system evolves, but do not help really to discuss the dynamic of the system up these potential equilibria.

This problem is clearly involved in the discussion we made about the inter-domain routing application in first section. In this example, whereas some experimental simulations stabilize, some other do not, without clear understanding.

Evolutionary game theory (see *e.g.* [HS03, Cre03]) provides some models and results for that. But we think that proof techniques are missing to discuss completely dynamics of distributed algorithms, and that this whole field requires further investigations.

In this project, we plan the following:

- Investigate models in the spirit of those related to the example taken from inter-domain routing. Our purpose is to investigate how to better model the dynamical relationships between partners during the evolution toward the equilibria, in particular in this context.
- Provide sufficient conditions, that could derive cases where some dynamical properties of the system can be formally established. For example, for the inter-domain routing application, sufficient conditions that imply the stabilization, when the traffic is fixed.
- Confront analytical predictions to simulations. We believe this is a good way to validate the models.

2.6 Self-stabilization Aspects

There exist numerous ways to prove a distributed system self-stabilizing. (see [BBFM01, DT03, GM91, Kes88, TNPK01]). The first technique, and certainly the most used one, is the convergence steps (introduced in [GM91]). Another tool, that is closer to the notion of equilibrium, consists in using potential functions [Kes88]. The overall idea is to find a function f whose domain is the set of states of the system and whose co-domain $\mathcal{R}$ is such that, for any possible evolution of the system, f is monotonous until it reaches after finite time a threshold value after which the behavior of the system is correct.

The large majority of self-stabilizing solutions in large distributed systems is based on the cooperation of the processes in the system against an adversary that can be seen as the environment. The environment may corrupt arbitrarily the values of the variables, the contents of the exchanged messages, and the scheduling of processes, so that recovering from such hazards is made harder (see *e.g.* [DIM95]).

In this project, we wish to push the hardness of the problem a bit further: among the cooperating processes, some may be "uncooperative", *e.g.* be malicious and try to cause havoc in the system, or simply try to get commercial benefit from their unpleasant actions. In other words, not only the environment may cause arbitrary corruptions or scheduling, but participating processes may also harm the system behavior. We plan to study two separate cases:

- Design systems that are self-stabilizing in spite of the presence of Byzantine (*i.e.* malicious) processes, that have unlimited resources. Those systems would typically be used when the environment can be controlled or trusted (*e.g.* a network of sensors placed in a dangerous area).
- Design systems that are *competitive* self-stabilizing. Overall all processes aim at the same (commercial) goal, but their personal goals may differ from the personal goals of other processes. Those systems would typically be used in environments where protocols and formats are well known and agreed among all partners, but where personal goals are hard to guess from the outside. Obviously, and unlike the previous case, processes would not get access to unlimited resources.

2.7 Complexity Issues

There has been an important series of papers related to complexity questions about computation of equilibria: see *e.g.* the survey [MM96]. For example, Nash equilibria can be computed using Lemke-Howson algorithm if the game is in normal form [LH64], or Lemke algorithm if it is in extensive form [vS02, KMvS96]. The worst case of these algorithms is exponential, but the exact complexity of these problems is a well known open question [Pap01]. It is known that the question whether there exist some Nash equilibria with some properties lead to NP-hard questions [GZ89]. Computing equilibria for stronger notions of equilibria can be realized using methods based on manipulation of polynomials and semi-algebraic sets [MM96].

Whereas it seems to be hard to compute Nash equilibria of a given system, the question of verifying if a given configuration is a Nash equilibria is easier [Pap01].

In this project, we plan the following:

- Investigate methods to verify equilibria efficiently. We intend to contribute to research in the spirit of [FMdR04] where methods for testing properties of strings have been devised. Our purpose is to understand if it is possible to derive techniques, that given some notion of equilibrium, such as the ϵ-equilibrium notion [LMM03], and some matrix describing some game, would determine whether this matrix is far from an equilibrium for some distance.
- Investigate, through complexity and computability theory tools, the limits of solutions that game theory can derive for distributed algorithmic. In particular, the notions of stability that will be proposed in this project are expected to include notions of approximation and robustness. We plan to investigate trade-offs between approximation and complexity for these notions.

3 Intended results

Partie à rédiger en Anglais.
On détaillera l'échéancier des résultats et réalisations intermédiaires et finaux attendus. On précisera les risques scientifiques qui seront pris. On discutera de l'impact potentiel de ce projet sur les scènes européenne et internationale.

3.1 Summary of tasks

We plan to concentrate our studies on three main tasks: *(i)* Modeling, *(ii)* Algorithm design, and *(iii)* Evaluation.

Modeling. We will discuss the involved notions of stability relatively to problems occurring in the main two applications we mentioned.

Task 1.1 We will define notions of stability in models that encompass the two main application domains that we considered (inter-domain routing and sensor networks).

Task 1.2 The model from [BBEV05] will be completed and expanded to include the notions of stability in the context of Inter-domain routing. This task will be carried out using inputs from industrial partners (such as Alcatel in France).

Task 1.3 The notion of *competitive* self-stabilization will be defined. In particular, necessary and sufficient conditions are to be defined to characterize a set of problems that can be solved in this model. The risk here is that many previous studies that combine self-stabilization with extra properties are intractable [AH89].

Task 1.4 Models for dynamical aspects involved in applications will be provided. In particular, models for interactions between partners in inter-domain routing application during the evolution toward stability.

Task 1.5 Very few previous works concentrate on dynamical aspects involved in algorithmic game theory solutions. We plan to investigate models and sufficient conditions that allow to establish some dynamical properties of such systems. This may reveal several impossibility results.

Task 1.6 Very few previous works concentrate on solving distributed problems in a self-stabilizing way that can also tolerate malicious behavior of some processes. So far, only local problems were considered. We plan to further study which problems can be solved in this context. Again, combining self-stabilization with resilience to malicious behavior may reveal several impossibility results.

Algorithm design. In the models defined by Tasks 1.1-1.4, and taking into account the possible impossibility results and complexity bounds resulting from Task 1.5-1.6, we will design sequential and distributed algorithms for the two main application domains that we consider.

Task 2.1 Distributed algorithms for Inter-domain routing will be designed, taking into account the commercial nature of routing and the economic interests of the processes.

Task 2.2 Sequential algorithms for sensor network distribution (or placement) for various problems involving cost of sensors, battery lifetime, and fault tolerance.

Task 2.3 Distributed algorithms for Inter-domain routing will be designed, with formally established dynamical guarantees.

Task 2.4 Distributed algorithms (possibly self-stabilizing) for sensor networks that can withstand malicious behavior by a portion of the nodes.

Task 2.5 Distributed competitive self-stabilizing algorithms, for problems occurring both in inter-domain routing and sensor networks.

Evaluation. All proposed solutions in Tasks 2.1-2.5 will be proved analytically and/or by simulation.

Task 3.1 Complexity of all solutions will be addressed and discussed as far as current knowledge enables it.

Task 3.2 If, for a given problem, no exact solution, or efficient solution exist or is found, formally studied approximations will be considered.

Task 3.3 Investigate methods to verify equilibria efficiently.

Task 3.4 For all designed solutions (even those not falling in the category of Tasks 3.1-3.3), simulate the solutions to get quantitative experimental results.

3.2 Task allocation

The tasks are assigned to teams as follows:

Nancy	1.1	1.2	1.3	1.4	1.5		2.1	2.2	2.3		2.5	3.1	3.2		3.4
Orsay	1.1		1.3			1.6	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	
Versailles	1.1	1.2		1.4			2.1		2.3	2.4	2.5		3.2		3.4

3.3 Schedule

The planned schedule is as follows:

0-6 months	Tasks 1.1, 1.2, 1.3, 1.4, 1.5, 1.6
6-12 months	Tasks 1.1, 1.2, 1.3, 1.4, 1.5, 1.6
12-18 months	Tasks 1.1, 1.2, 1.6, 2.1, 2.2, 2.4, 2.5,
18-24 months	Tasks 2.1, 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4
24-30 months	Tasks 2.1, 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4
30-36 months	Tasks 3.1, 3.2, 3.3, 3.4

3.4 Expected results from CDDs

Competitive and Byzantine resilient Stabilization. The main task of this CDD is to design and study self-stabilizing distributed algorithms when *(i)* there is competition between cooperating processes, and *(ii)* there is a subset of the nodes that can exhibit malicious behavior. This typically relates to Tasks 2.4, 2.5, 3.1, 3.2, and 3.4. This CDD is to be at the "Ingénieur expert" level and starts at month 12 for at least 12 months (possibly 18).

Mechanism Design & Dynamical Aspects The main task of this CDD will be to contribute to improve the model from [BBEV05] and to extend mechanism design techniques to deal with proposed notions of stability, as well as to deal with dynamical aspects. This typically relates to Tasks 1.1, 1.2, 1.4, 1.5, 2.3, 2.5, 3.4. This CDD will be at the "Ingénieur expert" level and starts at month 0 for 36 months. He or she will be based on LORIA at year 1, PRISM at year 2, and LORIA at year 3. The mission of this CDD will explicitly mention cooperation and regular exchanges with all sites.

Evaluations We plan to hire several persons to implement our algorithms and simulate them on realistic platforms, and/or perform numerical analysis on them. We plan to have a 4 months positions every year at the engineer level. Those positions will typically work on Tasks 3.2, 3.3, and 3.4.

4 References

On donnera ici les références bibliographiques citées dans la description scientifique

References

[ADTW03] Elliot Anshelevich, Anirban Dasgupta, Eva Tardos, and Tom Wexler. Near-optimal network design with selfish agents. In *Proceedings of the thirty-fifth annual ACM symposium on Theory of computing*, pages 511–520. ACM Press, 2003.

[AH89] M. Abadi and J. Y. Halpern. Decidability and expressiveness for first-order logics of probability. In *focs89*, pages 148–153, 1989.

[AMS96] Noga Alon, Yossi Matias, and Mario Szegedy. The space complexity of approximating the frequency moments. In *Proceedings of the Twenty-Eighth Annual ACM Symposium on the Theory of Computing*, pages 20–29, Philadelphia, Pennsylvania, 22–24 May 1996.

[BBEV05] D. Barth, L. Blin, L. Echabbi, and S. Vial. Distributed cost management in a selfish multi-operators BGP network. *Next Generation Internet Networks proceedings*, 2005.

[BBFM01] J. Beauquier, B. Bérard, L. Fribourg, and F. Magniette. Proving convergence of self-stabilizing systems using first-order rewriting and regular languages. *Distributed Computing*, 14(2):83–95, 2001.

[BDG88] José Luis Balcázar, Josep Diáz, and Joaquim Gabarró. *Structural Complexity I & II.* EATCS Monographs on Theoretical Computer Science, 1988.

[Bel58] Richard Bellman. On a routing problem. *Quaterly of Applied Mathematics*, 1:57–90, 1958.

[BH05] Olivier Bournez and Emmanuel Hainry. Recursive analysis characterized as a class of real recursive functions. *Fundamenta Informaticae*, 2005. to appear.

[BH04a] Olivier Bournez and Emmanuel Hainry. An analog characterization of elementarily computable functions over the real numbers. volume 3142 of *Lecture Notes in Computer Science*, pages 269–280, Turku, Finland, 2004. Springer.

[BH04b] Olivier Bournez and Emmanuel Hainry. Real recursive functions and real extentions of recursive functions. In Maurice Margenstern, editor, *Machines, Computations and Universality (MCU'2004)*, volume 3354 of *Lecture Notes in Computer Science*, Saint-Petersburg, Russia, September 2004.

[Bou99] Olivier Bournez. *Complexité Algorithmique des Systèmes Dynamiques Continus et Hybrides.* PhD thesis, Ecole Normale Supérieure de Lyon, Janvier 1999.

[Cla71] E.H. Clarke. Multipart pricing of public goods. *Public Choice*, pages 17–33, 1971.

[CLR90] T. H. Cormen, C. E. Leiserson, and R. L. Rivest. *Introduction to Algorithms*. MIT Press, 1990.

[Cre03] R. Cressman. *Evolutionary dynamics and extensive form games*. MIT Press, 2003.

[CSM04] José R. Correa, Andreas S. Schulz, and Nicolás E. Stier Moses. Selfish routing in capacitated networks. *Math. Oper. Res.*, 29(4):961–976, 2004.

[Czu03] Artur Czumaj. *Handbook of Scheduling: Algorithms, Models, and Performance Analysis*, chapter Selfish Routing on the Internet. CRC Press, 03? Avalaible on *http://web.njit.edu/ czumaj/PUBLICATIONS/Selfish-Routing-Survey-2003.html*.

[Dij74] E. W. Dijkstra. Self stabilizing systems in spite of distributed control. *Communications of the ACM*, 17(11):643–644, 1974.

[DIM95] Shlomi Dolev, Amos Israeli, and Shlomo Moran. Analyzing expected time by scheduler-luck games. *IEEE Trans. Softw. Eng.*, 21(5):429–439, 1995.

[Dol00] S. Dolev. *Self-stabilization*. The MIT Press, 2000.

[DT03] B. Ducourthial and S. Tixeuil. Self-stabilization with path algebra. *Theoretical Computer Science*, 293(1):219–236, 2003.

[DV04] Devanur and Vazirani. The spending constraint model for market equilibrium: Algorithmic, existence and uniqueness results [extended abstract]. In *STOC: ACM Symposium on Theory of Computing (STOC)*, 2004.

[FF62] L.R. Ford and D.R. Fulkerson. *Flows in Networks*. Princeton University Press, Princeton, NJ, 1962.

[FGL+03] Feldmann, Gairing, Lucking, Monien, and Rode. Selfish routing in non-cooperative networks: A survey. In *MFCS: Symposium on Mathematical Foundations of Computer Science*, 2003.

[FKSS01] Joan Feigenbaum, Arvind Krishnamurthy, Rahul Sami, and Scott Shenker. Approximation and collusion in multicast cost sharing. In *Proceedings of the 3rd ACM Conference on Electronic Commerce (EC-01)*, pages 253–255, New York, October 14–17 2001. ACM Press.

[FKSS03] Joan Feigenbaum, Arvind Krishnamurthy, Sami Sami, and Scott Shenker. Hardness results for multicast cost sharing. *Theoretical Computer Science*, 304(1–3):215–236, July 2003.

[FMdR04] Fischer, Magniez, and de Rougemont. Property and equivalence testing on strings. In *ECCCTR: Electronic Colloquium on Computational Complexity, technical reports*, 2004.

[FPS01] Joan Feigenbaum, Christos H. Papadimitriou, and Scott Shenker. Sharing the cost of multicast transmissions. *Journal of Computer and System Sciences*, 63(1):21–41, 2001.

[FPSS02] J. Feigenbaum, C. Papadimitriou, R. Sami, and S. Shenker. A BGP-based mechanism for lowest-cost routing. In *Proceedings of the 2002 ACM Symposium on Principles of Distributed Computing*, pages 173–182, New York, NY, July 2002.

[GJS04] Xiaojie Gao, Kamal Jain, and Leonard J. Schulman. Fair and efficient router congestion control. In *Proceedings of the fifteenth annual ACM-SIAM symposium on Discrete algorithms*, pages 1050–1059. Society for Industrial and Applied Mathematics, 2004.

[GM91] M. G. Gouda and N. Multari. Stabilizing communication protocols. *IEEE Transactions on Computers*, 40(4):448–458, 1991.

[Gro73] T. Groves. Incentives in teams. *Econometrica*, 41:617–663, 1973.

[GZ89] Itzhak Gilboa and Eitan Zemel. Nash and correlated equilibria: Some complexity considerations. *Games and Economic Behavior*, 1:80–93, 1989.

[HS03] J. Hofbauer and K. Sigmund. Evolutionary game dynamics. *Bulletin of the American Mathematical Society*, 4:479–519, 2003.

[Kes88] J.L.W. Kessels. An exercise in proving self-stabilization with a variant function. *Information Processing Letters*, 29(1):39–42, 1988.

[KLS01] Michael J. Kearns, Michael L. Littman, and Satinder P. Singh. Graphical models for game theory. In *Proceedings of the 17th Conference in Uncertainty in Artificial Intelligence*, pages 253–260. Morgan Kaufmann Publishers Inc., 2001.

[KMvS96] Daphne Koller, Nimrod Megiddo, and Bernhard von Stengel. Efficient computation of equilibria for extensive two-person games. *Games and Economic Behavior*, 14(2):247–259, 6 1996. available at http://ideas.repec.org/a/eee/gamebe/v14y1996i2p247-259.html.

[KW82] David Kreps and Robert Wilson. Sequential equilibria. *Econometrica*, 50:863–894, 1982.

[LH64] C. Lemke and J. Howson. Equilibrium points of bimatrix games. *Journal of the Society for Industrial and Applied Mathematics*, 12:413–423, 1964.

[LMM03] Richard J. Lipton, Evangelos Markakis, and Aranyak Mehta. Playing large games using simple strategies. In *Proceedings of the 4th ACM conference on Electronic commerce*, pages 36–41. ACM Press, 2003.

[Lyn97] N. Lynch. *Distributed Algorithms.* Morgan Kaufmann Publishers, Inc, 1997.

[McM94] J. McMillan. Selling spectrum rights. *Journal of Economic Perspectives*, pages 145–162, 1994.

[MM96] R. McKelvey and A. McLennan. *Handbook of Computational Economics*, chapter Computation of equilibria in finite games. 1996.

[Mye78] Roger Myerson. Refinements of the nash equilibrium concept. *International Journal of Game Theory*, 7, 1978.

[Nas50] John F. Nash. Equilibrium points in n-person games. *Proc. of the National Academy of Sciences*, 36:48–49, 1950.

[NR99] Noam Nisan and Amir Ronen. Algorithmic mechanism design (extended abstract). In *Proceedings of the thirty-first annual ACM symposium on Theory of computing*, pages 129–140. ACM Press, 1999.

[NR00] Nisan and Ronen. Computationally feasible VCG mechanisms. In *CECOMM: ACM Conference on Electronic Commerce*, 2000.

[NWD03a] T.-W. J. Ngan, D. S. Wallach, and P. Druschel. The design of a distributed rating scheme for peer-to-peer systems. In *Proceedings of the Workshop on the Economics of Peer-to-Peer Systems*, 2003.

[NWD03b] T.-W. J. Ngan, D. S. Wallach, and P. Druschel. Enforcing fair sharing of peer-to-peer resources, February 2003.

[OR94] Osbourne and Rubinstein. *A Course in Game Theory.* MIT Press, 1994.

[Pap01] Christos Papadimitriou. Algorithms, games, and the Internet. In ACM, editor, *Proceedings of the 33rd Annual ACM Symposium on Theory of Computing: Hersonissos, Crete, Greece, July 6–8, 2001*, pages 749–753, New York, NY, USA, 2001. ACM Press.

[Sel75] Reinhard Selten. Reexamination of the perfectness concept for equilibrium points in extensive games. *International Journal of Game Theory*, 4:25–55, 1975.

[TNPK01] T. Tsuchiya, S. Nagano, R. B. Paidi, and T. Kikuno. Symbolic model checking for self-stabilizing algorithms. *IEEE Transactions on Parallel and Distributed Systems*, 12(1):81–95, 2001.

[vD87] Eric van Damme. *Stability and perfection of Nash equilibria*. Springer-Verlag, 1987.

[Vic61] W. Vickrey. Counterspeculation, auctions and competitive sealed tenders. *Journal of Finance*, pages 8–37, 1961.

[vS02] B. von Stengel. *Computing equilibria for two-person games*, volume 3, chapter Chapter 45, Handbook of Game Theory, pages 1723–1759. North-Holland, Amsterdam, 2002.

5 Bibliographical references of the researchers involved in the project

Pour chaque (enseignant-)chercheur participant, lister de 3 à 5 publications, logiciels ou brevets les plus significatifs, en relation avec la thématique du projet proposé.

5.1 Partners

Three partners are involved in this project:

1. *LORIA* laboratory (Laboratoire de Recherche en Informatique et ses Applications) from Nancy.
2. *LRI* laboratory (Laboratoire de Recherche en Informatique) from Paris XI University.
   Two groups are involved in LRI: The “Parallelism” group, and the “Algorithms and Complexity” group.
3. *PRISM* laboratory (Laboratoire de Recherche en Informatique) from Versailles St-Quentin en Yvelines University.

5.2 Participants, and bibliographical references

Participants in each site are:

1. LORIA, (Laboratoire Lorrain de Recherche en Informatique et ses Applications), Nancy.
   (a) Olivier Bournez, Chargé de Recherche INRIA. *www.loria.fr/bournez*.
   Research related to computational models, in particular work in progress related to models of economic inspiration.
   Selected Publications: [9, 10, 8].
   (b) Johanne Cohen, Chargée de Recherche CNRS. *www.loria.fr/jcohen*.
   Research related to graph theory, algorithmic for telecommunications, related complexity and optimization problems.
   Selected Publications: [7, 5, 13]

(c) Loubna Echabbi, Post-Doctorante INRIA (October 1st 2005- September 30th 2006). *www.prism.uvsq.fr/users/lechabbi/*.
PhD thesis on problems related to the pricing of quality of service in telecommunication networks.
Selected Publications: [1, 2, 3]

2. LRI (Laboratoire de recherche en informatique), Paris XI, Orsay.

- From research team "Parallelism":
  (a) Sylvie Delaet, Maitre de Conférence. *http://www.lri.fr/̃delaet/*.
  Research related to auto-stabilization and distributed algorithmic.
  Selected Publications: [15, 16, 17]
  (b) Sébastien Tixeuil. Maitre de Conférence en Délégation. *http://www.lri.fr/̃tixeuil/*.
  Research related to auto-stabilization and distributed algorihmic.
  Selected Publications: [20, 11, 29]
- From research team "Algorithms and Complexity":
  (a) Michel de Rougemont. Professeur. *www.lri.fr/̃mdr/*.
  Research related to complexity, and in particular complexity of computing and verifying equilibria in game theory. Coordinator of a Master proposition related to algorithmic game theory.
  Selected Publications: [24, 26, 14].
  (b) Frédéric Magniez. Chargé de Recherche CNRS. *www.lri.fr/̃magniez/*.
  Research related to test and auto-test, and in particular work in progress on approximation of equilibria in game theory.
  Selected Publications: [25, 26, 23].
  (c) Miklos Santha. Directeur de Recherche CNRS. *www.lri.fr/̃santha/*.
  Research related to complexity, quantum computation, algorithmic game theory, test and auto-test.
  Selected Publications: [23, 21, 22]
  (d) Adrien Vielleribière. PhD student.
  PhD Student working on games for integration of datas in autonomous data bases.

3. PRISM (Laboratoire de Recherche en Informatique), Université de Versailles St-Quentin en Yvelines.

(a) Dominique Barth, Professeur. *www.prism.uvsq.fr/users/barth/*.
Research related to algorithmic for telecomunication networks, and about pricing on networks. Work in progress about pricing of inter-domain routing with industrial partners Alcatel and France Telecom.
Selected Publications: [1, 2, 6]

(b) Hervé Fournier, Maitre de Conférences. *www.prism.uvsq.fr/users/hefou/*.
Research related to complexity theory, and in particular to algebraic complexity theory. Work in progress on problems related to telecommunication networks.
Selected Publications: [4, 18, 12]

(c) Nihal Pekergin, Maitre de Conférences. *http://www.prism.uvsq.fr/administration/personnel/nih_fr.html*.
Research related to algorithmic for telecommunication networks.
Selected Publications: [28, 30, 27]

(d) Chahinez Hamlaoui, PhD student.
Research related to algorithmic for telecommunication networks.
Selected Publications: [19]

References

[1] D. Barth, L. Blin, L. Echabbi, and S. Vial. Distributed cost management in a selfish multi-operators bgp network. *Next Generation Internet Networks proceedings*, 2005.

[2] D. Barth and L. Echabbi. Distributed multi-link auctions for network ressource reservation and pricing. *Internet Charging and QoS Technology*, 3266:328–337, 2004.

[3] D. Barth, L. Echabbi, and F. Quessette. Evaluation of distributed auction strategies for requests admission control. In *conference on heterogeneous networks*, 2004.

[4] D. Barth and H. Fournier. A degree bound on decomposable trees. Technical Report 59, PRiSM, Université de Versailles, 2004. Submitted.

[5] Dominique Barth, Pascal Berthomé, and Johanne Cohen. The eulerian stretch of a digraph and the ending guarantee of a convergence routing. *Journal of Interconnection Networks (JOIN)*, 5(2):93–109, jun 2004.

[6] Dominique Barth, Johanne Cohen, and Corentin Durbach. Multicast tree allocation algorithms for distributed interactive simulation. *International Journal of High Performance Computing and Networking - IJHPCN.*, 2005.

[7] Dominique Barth, Johanne Cohen, Lynda Gastal, Thierry Mautor, and Stephane Rousseau. Fixed size and variable size packet models in an optical ring network: Complexity and simulations. In Cevdet Aykanat, Tugrul Dayar, and Ibrahim Korpeoglu, editors, *19th International Symposium on Computer and Information Sciences (ISCIS)*, volume 3280 of *Lecture Notes in Computer Science*, pages 238–246. Springer, Oct 2004.

[8] Olivier Bournez and Emmanuel Hainry. An analog characterization of elementarily computable functions over the real numbers. volume 3142 of *Lecture Notes in Computer Science*, pages 269–280, Turku, Finland, 2004. Springer.

[9] Olivier Bournez and Emmanuel Hainry. Elementarily computable functions over the real numbers and $\mathbb{R}$-sub-recursive functions. *Theoretical Computer Science*, 2005. to appear.

[10] Olivier Bournez and Emmanuel Hainry. Recursive analysis characterized as a class of real recursive functions. *Fundamenta Informaticae*, 2005. to appear.

[11] Yu Chen, Ajoy K. Datta, and Sébastien Tixeuil. Stabilizing inter-domain routing in the internet. *Journal of High Speed Networks*, page to appear, 2005.

[12] A. Chistov, H. Fournier, L. Gurvits, and P. Koiran. Vandermonde matrices, NP-completeness and transversal subspaces. *Foundations of Computational Mathematics*, 3(4):421–427, 2003.

[13] Johanne Cohen, Pierre Fraignaud, and Margarita Mitjana. Polynomial time algorithms for minimum-time broadcast in tree. *Theory of Computing Systems*, 35(6):641–665, 2002.

[14] Michel de Rougemont. Definable strategies and equilibria for games. In *International Conference on Electronic Business*, 2002.

[15] Sylvie Delaët, Duy-So Nguyen, and Sébastien Tixeuil. Stabilité et auto-stabilisation de bgp. In *Proceedings of Algotel 2003*, Banyuls, France, may 2003. INRIA.

[16] Sylvie Delaët, Duy-So Nguyen, and Sébastien Tixeuil. Stabilité et auto-stabilisation du routage inter-domaine dans internet. In *Proceedings of RIVF 2003*, pages 139–144, Hanoi, Vietnam, february 2003. Studia Informatica Universalis.

[17] Sylvie Delaët and Sébastien Tixeuil. Tolerating transient and intermittent failures. *Journal of Parallel and Distributed Computing*, 62(5):961–981, May 2002.

[18] H. Fournier. Quantifier rank for parity of embedded finite models. *Theoretical Computer Science (special issue MFCS'01)*, 295(1-3):153–169, 2003.

[19] Chahinez Hamlaoui. Exploitation des protocoles de découverte de services pour l'auto-configuration du plan de gestion. Stage de dea, Jun 2004.

[20] Ted Herman and Sébastien Tixeuil. A distributed tdma slot assignment algorithm for wireless sensor networks. In *Proceedings of the First Workshop on Algorithmic Aspects of Wireless Sensor Networks (AlgoSensors'2004)*, number 3121 in Lecture Notes in Computer Science, pages 45–58, Turku, Finland, July 2004. Springer-Verlag.

[21] G. Ivanyos K. Friedl and M. Santha. Efficient testing of groups. In *37th Symposium on Theory of Computing (STOC)*. ACM, 2005.

[22] Miklos Santha Yves F. Verhoeven Katalin Friedl, Gabor Ivanyos. On the black-box complexity of sperner's lemma-. In *15th International Symposium on Fundamentals of Computation Theory (FCT'05)*, August 2005. To appear.

[23] M. Kiwi, F. Magniez, and M. Santha. *Journal of Computer and System Sciences*.

[24] S. Laplante, R. Lassaigne, F. Magniez, S. Peyronnet, and M. de Rougemont. Probabilistic abstraction for model checking: An approach based on property testing. In *Proceedings of 17th IEEE Symposium on Logic in Computer Science*, pages 30–39, 2002.

[25] F. Magniez. Multi-linearity self-testing with relative error. *Theory of Computing Systems (TOCS)*, 2004. To appear.

[26] F. Magniez and M. de Rougemont. Property testing of regular tree languages. In *Proceedings of 31st International Colloquium on Automata, Languages and Programming*, volume 3142 of *Lecture Notes in Computer Science*, pages 932–944. Verlag, 2004.

[27] M. Ben Mamoun and N. Pekergin. Closed-form stochastic bounds on the stationary distribution of markov chains. *Probability in the Engineering and Informational Science*, 16, 2002.

[28] M. Ben Mamoun and N. Pekergin. Stochastic delay bounds of fair queueing policies through weighted round robin policies. *Performance Evaluation*, 47/2-3, 2002.

[29] Nathalie Mitton, Eric Fleury, Isabelle Guérin-Lassous, and Sébastien Tixeuil. Self-stabilization in self-organized wireless multihop networks. In *Proceedings of the 25th IEEE International Conference on Distributed Computing Systems Workshops (WWAN'05)*, pages 909–915, Columbus, Ohio, USA, June 2005. IEEE Press.

[30] N. Pekergin and Sana Younès. Stochastic model checking with stochastic somparison. In *European Performance Engineering Workshop*, 2005.

5.3 Other involvments of participants

- Dominique Barth is involved in ACI ALGOL (until 2007) at 40% and in ACI SR2I (until 2007) at 20%.
- Sylvie Delaet is involved in ACI SR2I (until 2007) at 50%.
- Michel de Rougemont is involved in ACI VERA (until 2006) at 20%.
- Frederic Magniez is currently involved in ACI VERA (until 2006) at 20%, and in ACI Réseaux Quantiques (until 2006) at 30%. Total: 50%.

- Miklos Santha is currently involved in ACI VERA (until 2006) at 30%, an in ACI Réseaux Quantiques (until 2006) at 30%. Total: 60%.
- Sébastien Tixeuil is involved in ACI SR2I (until 2007) at 50%, in ACI GRID explorer at 20%, and ACI FRAGILE at 50%. However, these 120% corresponds to 60% of his research time, since he is now in a "Delegation" position.