Acronyme / Acronym	MaCARoN		
Titre du projet	Bouger et Calculer: Agents, Robots et Réseaux		
Proposal title	Moving and Computing: Agents, Robots and Networks		
Comité d'évaluation / Evaluation panel	SIMI2		
Type de recherche / Type of research	■ Recherche Fondamentale / Basic Research ☐ Recherche Industrielle / Industrial Research ☐ Développement Expérimental : Experimental Development		
Aide totale demandée / Grant requested	306 228 €	**Durée du projet / Projet duration**	48 mois
Partenaire coordinateur / Coordinator partner	Identité du coordinateur (nom, prénom) : CHALOPIN Jérémie Identification de l'établissement (laboratoire, tutelle, entreprise...) : Laboratoire d'Informatique Fondamentale de Marseille, CNRS et Aix-Marseille Université		
Lien avec un projet du programme *Investissements d'Avenir* (IA) / Link with a project of the *Investment for the Future* programme	■ Oui ☐ Non si oui, préciser : Laboratoire d'Excellence Archimède Initiative d'Excellence A*MIDEX		
Comité d'évaluation auquel vous envisagez de soumettre une proposition de projet dans le cadre des appels à projets de l'ERC / Evaluation panel to which you plan to submit a proposal in the frame of the ERC calls for proposals	PE6: Computer Science and Informatics		

Personnes impliquées dans le projet / People involved in the project :

Pour chacune des personnes dont l'implication dans le projet est supérieure à 25% de son temps sur la totalité du projet (c'est-à-dire une moyenne de 3 personnes.mois par année de projet), préciser leur rattachement, leurs activités principales et leurs compétences propres en remplissant le tableau ci-dessous :

Etablissement/ Organisation	Nom/ Name	Prénom/ First name	Emploi actuel/ Position	Personne.mois/ PM	Rôle & responsabilité dans le projet / Contribution to the project
Personnel permanent / Permanent researchers					
LIF, CNRS	CHALOPIN	Jérémie	Chargé de recherche CNRS	36 (9/an)	Coordinator of the project Coordinator of Tasks 0, 1 and 5
LIF, Aix-Marseille Université & CNRS	DAS	Shantanu	Maître de conférences, Chaire CNRS	24 (6/an)	
LIF, Aix-Marseille Université & CNRS	GODARD	Emmanuel	Maître de conférences	24 (6/an)	Coordinator of Task 3
LaBRI, CNRS	ILCINKAS	David	Chargé de recherche CNRS	8 (2/an)	
LIF, Aix-Marseille Université & CNRS	LABOUREL	Arnaud	Maître de conférences	28 (7/an)	Coordinator of Task 2
LIF, Aix-Marseille Université & CNRS	NIEBERT	Peter	Maître de conférences	16 (4/an)	Coordinator of Task 4
LIF, Aix-Marseille Université & CNRS	REYNIER	Pierre-Alain	Maître de conférences	8 (2/an)	
Personnel non-permanent sans financement ANR demandé / Non-permanent researchers without ANR funding					
LIF, Aix-Marseille Université & CNRS	YUAN	Haitao	Doctorant CSC / Ecole Centrale Marseille	24	Haitao YUAN will start his PhD in September 2013 under the supervision of E. Godard
Personnel non-permanent avec financement ANR demandé / Non-permanent researchers with ANR funding					
			PhD Student	36	
			Postdoctoral researcher	12	

1. Résumé de la proposition de projet / Executive summary

There is an emerging trend in robotics : rather than by a few bulky robots, certain tasks can be performed by tiny robots, each with very limited capabilities. This trend is similar to the less recent trend about sensor networks, with sensors that are also of limited capabilities but deployed in huge number. This is the emergence of systems where elementary bricks are simple and cheap though can provide relatively complex collective behavior. From an algorithmic point of view, one need to consider a new computing paradigm « Moving and computing »: the study and design of systems where the computational entities themselves are capable of movement within the spatial universe they inhabit. The field has applications in areas as diverse as autonomous robots moving in a terrain, software agents moving in a network, autonomous intelligent vehicles, wireless mobile ad-hoc networks, and networks of mobile sensors; where the computational objectives are exploration, coordination and cooperation.

When considering the design of algorithms for mobile robots in a geometric environment, the modeling of the environment, i.e., the way the mobile entities have access to it, is crucial. The entities can have access to only limited aspects of the environment : e.g. where it can move. Indeed, in this setting, the robot main responsibility is to compute where to go next. Such a modeling implies the study of the graph of the possible locations, linked by the elementary moves. Such a graph does not have an arbitrary structure but inherit some combinatorial properties from its geometric context. In this framework, using the mobile agent model, from classical distributed computing, is very much relevant. The specificity of our study is

that the graphs under consideration are of geometric type (e.g. the visibility graph of a polygon). Moreover, it is known that adding more sensing capabilities will yield more efficient algorithms. A natural investigation is therefore to characterize what are the weakest kind of sensors, i.e., the kind of geometric information, that enable to solve efficiently problems such as exploration, map construction, rendezvous, ...

In contrast with the previous situation, in the case of mobile sensors, the computation is more how to react to moves and changes in the topology that are not directly under control. However, similarly, by using geometric properties, it is possible to improve the efficiency of algorithms, compare to algorithms using only combinatorial graphs properties. Hence, solving tasks such as broadcast, computing/repairing local structures, benefits from a deep understanding of the relationship generated by the actual topology of the sensor network, especially the possible dynamic evolutions of such networks. It is also possible to show that the "mobile agent" model is also relevant in this context, because it enables to use a simple computational structure within a complex data structure.

A distant goal for our research, that will be of importance in the near future, is to investigate thoroughly the interactions and evolutions of mobile agents in dynamic networks. More generally, our objective is to dramatically improve the models and algorithms for distributed robot computing. Such a study implies to get a better understanding of the relations between local, global and geometric properties shared by those problems and environments. We will benefit from tools and known results from geometric graph theory, discrete algebraic topology, computational geometry and timed systems. Last, part of the validation of this project's results will be done with « LED's CHAT » (`http://leds-chat.net/`): a modular light and sensor system developed at LIF, and currently subject to a technology transfer program with the aim of commercializing the technology to actual light applications.

2. CONTEXTE, POSITIONNEMENT ET OBJECTIFS DE LA PROPOSITION / CONTEXT, POSITION AND OBJECTIVES OF THE PROPOSAL

2.1. OBJECTIFS ET CARACTÈRE AMBITIEUX/NOVATEUR DU PROJET / OBJECTIVES, ORIGINALITY AND NOVELTY OF THE PROJECT

The advent of IPv6 with its address space for up to 2^{128} entities marks the transition from « computer networks » to « the internet of things ». This paradigm shift eventually requires that the « things », be they mobile communication devices, vehicles, robots, street lamps, traffic lights and more generally dynamic signaling, smart everyday objects, etc eventually constitute themselves the networks they use. Ad-hoc networks, wireless sensor networks etc are examples of such networks which have in common :

- decentralized organisation ;
- mobility of nodes ;
- power consumption restrictions with implications for communication bandwidth ;
- limited reliability ;
- limited computation and storage capability of nodes.

In case of low power wireless networks, direct links between nodes are possible depending on their geometric distance. The resulting network topology is a graph with particular properties. Changes in the graph due to node movement or failure are also not arbitrary.

Even if it is in principle possible to assign unique (MAC) addresses to nodes, the nodes are naturally anonymous in many cases, in particular in the case of modular systems where each module is initially identical. In the case of a sensor network, the identity of a sensor may be less important than its geometric position.

Additional aspects come into play for swarms of microrobots, an emerging trend in robotics: rather than by a few bulky robots, certain tasks can be performed by tiny, maybe insectlike, robots, each with very limited capabilities. Examples of applications include mapping and surveillance in hostile environments, where the swarm of microrobots is more robust, since the failure of a certain number of individuals need not corrupt the task performed by the collective. Several aspects of the microrobots are of major interest from a « distributed algorithm » point of view: the fact that they move while each having a limited vision of their environment as well as a limited communication and possibly a weak notion of its geographic position. Again, the « identity » of an individual robot is less important than its position. As a consequence, the motion of the robots is an integral part of the distributed algorithms themselves. Examples include the « gathering and dispersion » problems studied in the literature: how can a group of robots moving about in 2D space gather at a common position, or to the contrary, how can they disperse.

While the microrobots introduce a natural notion of « mobility » into (geometric) distributed algorithms, there exists another notion of mobility in the conception of distributed algorithms for large networks: a certain number of « mobile agents » that are part of the software and can pass over data links from node to node in the network, taking its « state » along, and possibly leaving marks behind. The design of distributed algorithms with mobile agents has many advantages. Instead of moving the (massive) data across the network to a processing host, a (small) agent can move to the host storing the data and handle it there, thus reducing the network load. In systems with high latency and frequent communication failures, a mobile agent dispatched on a node can continue to work without waiting for the network to reestablish, thus improving the overall efficiency of distributed algorithms. In heterogeneous systems, mobile agents can be used to abstract from particular communication protocols and node types. The knowledge of structural properties of the topology as a consequence of the application domain, e.g. geometric networks, can be exploited in algorithm design.

As a summary, there are several notions of mobility as well as networks with a geometric meaning, which in turn, have consequences for the network topology. It is the aim of this project to improve the understanding of distributed algorithms for networks of the described kind, on the one hand to study their limitations and on the other hand to contribute to improved efficiency of algorithms.

2.2. ÉTAT DE L'ART / STATE OF THE ART

Mobile agents in networks. Mobile agent systems are distributed environment in which the nodes of the network are passive and some mobile agents are in charge of the execution of the algorithm. The network is represented by a graph and the agents can move from one node to another along the edges of the graph. In the literature, there exist many different models of mobile agent systems: the system can be synchronous or asynchronous, the agents can have ids or not, the agent can communicate by leaving tokens or messages on the nodes they visit or they cannot communicate without meeting each other, the size of the memory of each agent is finite, or logarithmic (in the size of the graph), polynomial, or infinite, …

For these models, there exist a lot of results concerning exploration, map construction, and rendezvous. An exploration algorithm enables a single mobile agent to traverse all the nodes of an unknown network and to stop once this is done. A map construction algorithm enables a single mobile agent to build a map of the underlying network. A rendezvous algorithm enables to gather on a single node two (or more) agents that are initially scattered all over the network.

There exist a large amount of results obtained about these problems in the literature. These problems are fundamental in distributed computing since the algorithms that are designed to solve these problems can then be used as building blocks to solve more specific problems. For example, in order to build a map of its environment, an agent has to explore it. These problems are also interesting since they enable to compare the computational power of different models of mobile agent systems. Furthermore, the combinatorial and algorithmic tools introduced to solve these problems are usually useful to characterize what can be computed in the different models.

These problems become straightforward when the nodes of the graph are labeled by distinct identifiers. In this case, the map construction problem is equivalent to the exploration problem and once each agent has built a map, they can gather on the node with the lowest identifier.

These problems become more challenging in anonymous networks, i.e., in networks where nodes do not have ids. For the exploration problem, Reingold [45] showed that provided with a bound on the size of the network, an agent with a logarithmic memory can explore any anonymous undirected graph if it can retrace its movements. However, when the agents cannot leave marks on nodes, it is well known that there exist graphs where it is impossible to solve the map construction problem; these graphs are too “symmetric” and the agents cannot distinguish the different nodes they visit. This notion of symmetricity is expressed using graph coverings and fibrations that are locally bijective graph homomorphisms [2, 6]. An important notion in this setting is the notion of minimum base (or quotient graph [51]): the minimum base B of a graph G is the smallest graph that is undistinguishable from G by an agent moving in G. The minimum base of a graph G encodes the maximum amount of information an agent can learn about its environment G.

In the literature, there exist a large number of papers considering the rendezvous problem for two agents that have distinct ids that are used to break initial symmetries [20, 24, 48]. When the agents have no ids, rendezvous cannot always be solved. Characterizations and universal algorithms for rendezvous have been given for different models [10, 16, 22].

There exists also a lot of results concerning specific topologies: trees [17, 27, 28], rings [25, 29], torus [4], etc. For these specific topologies, some efficient rendezvous algorithms have been given: either one tries to minimize the time or the number of moves needed to solve the task, or one wants to minimize the memory needed by the agents to solve the task. Considering specific topologies enables also to provide specific algorithms and to show their optimality by exhibiting some lower bounds. Note that for general graphs, for most of the models that exist in the literature, there is a huge gap between the complexity of the best algorithms known so far and the known lower bounds for the problem.

Recent works in rendezvous [3, 15] assume that the agents knows their initial position and are fully aware of the topology of the networks. Such assumption, partly fueled by the availability and the expansion of Global Positioning System (GPS), is called *location awareness*. This assumption allows very efficient rendezvous algorithms in both synchronous and asynchronous settings. Indeed, the algorithm are either asymptotically optimal (lines, grids, trees in synchronous setting [15]) or optimal up to a logarithmic multiplicative factor (arbitrary graphs in synchronous setting [15] and grids in asynchronous setting [3]).

Mobile robots in geometric environments. In the geometric scenario, the agents (often called robots in this case) move inside a geometric environment. Usually, the environment is modeled as a polygon (with or without holes called obstacles) or the plane. The problems are similar to those considered in the graphs scenario : exploration, map construction, and rendezvous.

In order to explore a polygon modeling its environment, the robot must see (explore) all points inside it. Two models of visibility are often considered: the *unlimited vision*, when the robot situated at a point p of the terrain explores (sees) all points q of the terrain for which the segment pq belongs to the terrain, and the *limited vision*, when we require additionally that the distance between p and q be at most 1. An exploration algorithm is said to be competitive if the ratio of the length of the algorithm trajectory over the length of the best exploration trajectory is bounded. One of the most important works for unlimited vision is [23]. The authors gave a 2-competitive algorithm for rectilinear polygon exploration without obstacles. The case of non-rectilinear polygons (without obstacles) was also studied in [32] and competitive algorithms were given. For polygonal environments with an arbitrary number of polygonal obstacles, it was shown in [23] that no competitive strategy exists. Exploration of polygons by a robot with limited vision has been studied in [30, 33, 37]. However, only one paper gives a competitive online algorithm to explore rectilinear polygons with limited vision [19].

Another model of robot was introduced in [47]. This model called *simple robot* is an robot that can only move from a vertex to a visible vertex of the polygon modeling the environment. Moreover, it can only sense little information from the environment such as angles between vertices seen from the current vertex or the distances to all visible vertices. The study of this model has been the subject of several works [5, 7, 11, 47]. In this setting, the goal is to determine if an agent can reconstruct the polygon (or its visibility graph) depending on the moves it can perform (it can either move only on the boundary of the polygon, or move freely across the polygon to any visible vertex) and on the sensors it is equipped with (e.g., it can compute angles between visible vertices, or it can compute distances to visible vertices).

The rendezvous problem has also been studied in the geometric scenario . The main benchmarks of performance for this problem is the distance traveled by the agents before they meet. The polygons [18], or the plane [1, 20, 26] have been studied.

From quasi-static networks ... Designing algorithms for static networks is an area that has been studied with numerous approach (distributed or not, centralized / decentralized, online offline, ...). This is one of the main themes of distributed computing. Designing algorithms for dynamic networks, where the network structure can be modified during the computation is less understood. Numerous research project exist about systems where the origin of the dynamicity is from faults (consequences being deleting or adding nodes or edges to the network). Indeed, fault-tolerance is probably one of the main endeavor in distributed computing. However, faults are in general of limited scope, in limited number and, above all, are considered as anomalies in respect to the normal and correct behavior of the system.

The study of the properties of algorithms for systems where network faults are really important, even unlimited is at the heart of the self-stabilization area. The goal of this research area is to design algorithms that, even operating in such extreme conditions are nonetheless able to provide correct solutions *if the system is stable on a long enough period.* Self-stabilization is actually an *over-approximation* of faults or of the system dynamics by a failure that is total but temporary. In this respect, the study of the exact impact of the real dynamic behavior of the system can not be realized. Moreover, in this case, we are also in the situation where the changes in the network structure are considered as faults, anomalies.

... To highly dynamic networks So, why not consider systems that are never stable, where the network is never connected at a given time, where the number of changes is not bounded and changes are continuously occurring, where these changes are not considered anomalies but are an integral part of the system at hand. Such highly dynamic systems do exist, and they are actually quite common, and they are becoming pervasive. A class of such systems is mobile ad hoc networks: the network topology, where communications occur when two entities are within their communication range, is continuously modified. This modifications can be very important; the network can be not connected, at least according to the classical signification of end-to-end paths between pairs of contemporary nodes. The network can actually be disconnected at any instant.

This infrastructureless and highly dynamic networks have been called ”delay-tolerant networks”, ”fault tolerant networks”, ”opportunistic networks” and have long been studied by the community of engineers, and more recently by the distributed algorithms research community; in particular for problems related to broadcast and routing, see e.g. [34, 41, 53]. In such networks, the protocol designer has no a priori knowledge or control other the trajectories of the entities. However, such highly dynamic conditions can also occur when the movements are predictable, for example for periodic or cyclic routes, like in public transportation systems with fixed schedules, low orbit satellites (LEO), etc... (see [42, 52]). Interestingly, similar complex dynamics can also occur in environments where there is absolutely no mobility at all, e.g., in social networks [13, 38].

It is also worth noting that in order to investigate these dynamic networks, most of the concepts defined for graphs and networks (path, distance, diameter, connected component and so on ...) have no signification within a temporal context. Indeed, all concepts of classical connexity have to be extended to a temporal version in order to take into account the realities of the environments that we are modeling.

3. PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DU PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROJECT ORGANIZATION

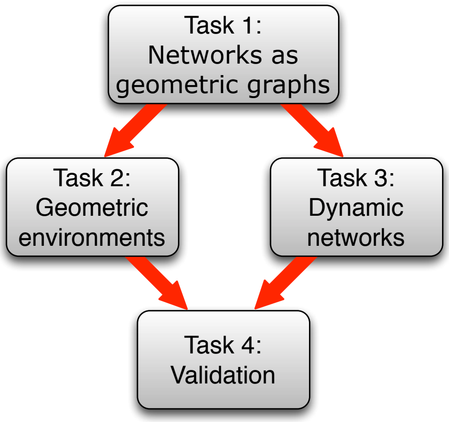


Figure 1: Dependencies between the different tasks.

3.1. PROGRAMME SCIENTIFIQUE ET STRUCTURATION DU PROJET/ SCIENTIFIC PROGRAMME AND PROJECT STRUCTURE

The aim of our project is to design efficient algorithms for distributed systems that have geometric properties and can be dynamic. Our project is divided in 6 tasks:

- Task 0: Management of the project
- Task 1: Networks as geometric graphs
- Task 2: Geometric environments
- Task 3: Dynamic networks
- Task 4: Validation
- Task 5: Complete evaluation of the work achieved inside the project

Tasks 0 and 5 concern the management and the organization of our project. Tasks 1, 2, 3, 4 describe the scientific problems we want to address. The dependencies of these tasks are represented in Figure 1

In tasks 1, 2, and 3, we are interested in providing efficient algorithms for mobile agents and networks relying on the geometric and dynamic properties of the environment. In task 1, we are interested in considering special classes of graphs that arise from geometric environments and to use their combinatorial properties to design efficient distributed algorithms. In task 2, we want to consider models where the robots, or the sensors can measure some geometric information about the environment (distances, angles, position, etc). In task 3, we want to consider highly dynamic networks and provide efficient algorithms for these networks, as well as studying mobile agents evolving in such environments. To handle these three tasks, one will need to use known techniques and algorithms from distributed computing, and to develop specific techniques to handle the models we want to consider. We will also use tools and known results from geometric graph theory (tasks 1 and 2), algebraic topology (task 1), computational geometry (task 2) and timed systems (task 3).

In task 4, we want to extend the ViSiDiA simulator for the study of models and algorithms introduced in the previous tasks, and we are particularly interested in dynamic networks. We also want to use « LED's CHAT », an actual distributed embedded system developed at LIF, as an application case study for our algorithms.

3.2. DESCRIPTION DES TRAVAUX PAR TÂCHE / DESCRIPTION BY TASK

Tâche 0/ Task 0: Project management

Objectives: The aim of this task is to perform the coordination of the project. This includes leading the project to on-time schedule fulfillment of the goals and request of approvals, driving and encouraging cooperation and coordination both within the project as well as with other ongoing projects and appropriate research activities.

Detailed program, methods, technical choices and solutions: We plan to organize two kinds of meetings in order to improve interaction between members of the project :

- Monthly meeting: we plan to organize a half day meeting each month for the whole team except David Ilcinkas. This meeting will take place in our laboratory (LIF). The main goal of these meetings will be to evaluate the progress of the project. For each task, the person in charge of the task will present the progress achieved. This will take the form of a one-hour presentation per meeting and per task. Moreover, in addition to these presentations, we will discuss on possible interactions and cooperation between tasks and members.
- Milestones: every year, before sending the year report to the ANR, we will have special meetings in order to evaluate the global progress of the project, w.r.t. the initial planning. After this evaluation, we will discuss to decide, if necessary, potential redefinitions of the objectives of the tasks. We also plan for these meetings to have external guests such as senior researchers in order to obtain external feedback on our work.

To simplify material exchanges, and to enhance the visibility of the project, we will realize a website for the project. Arnaud Labourel will be the responsible of the design of the website. This website will be based on a wiki technology with authentication. This will permit all members of the project to contribute to the content of the website. A SVN depository will also be created in order to facilitate collaborative work between members and external contributors.

Person in charge and involved members: Jérémie Chalopin will be in charge of this task.

Delivrable: The first deliverable will be the website which should be issued after six months. The other deliverables associated with this task are the activity reports which will be produced every year.

Tâche 1/ Task 1: Networks as Geometric graphs

Objectives: In this task, we want to consider mobile agents evolving in graphs arising from geometric environments. Some particular classes of graphs we are interested in are visibility graphs of polygons, unit disk graphs, planar triangulations, etc. We want to identify classes of graphs where weak agents can solve fundamental distributed problems efficiently.

We also want to study a model where each mobile agent has a local map of its current position. We conjecture that in this model, for a lot of the classes of geometric graphs we are interested in, mobile agents can solve exploration, map construction and rendezvous without any initial information on their environment.

Person in charge and involved members: Jérémie Chalopin will be in charge of this task. Shantanu Das, Emmanuel Godard and Arnaud Labourel will also be involved in this task, together with the PhD student funded by the project.

Detailed program, methods, technical choices and solutions: In this task, we will focus on mobile agents evolving in anonymous graphs. In the literature, one can find a lot of papers where it is assumed that the agents move in a network with a specific topology like a ring, a grid, a torus, or a tree. In these topologies, specific algorithms have been given for exploration, rendezvous, and map construction; one usually focuses on the efficiency of these algorithms. On the other hand, some results have been obtained for arbitrary graphs where no assumption is made on the topology. In this setting, the first goal is to characterize graphs where exploration, rendezvous or map construction can be solved; the next question is to determine what is the complexity of these problems, depending on the initial knowledge the agents have about the network, e.g., the agents can initially know the size of the network, or its diameter, or a bound on the size.

Specific classes of graphs. We are interested in considering specific graph classes with interesting combinatorial properties. In particular, we want to consider specific classes of graphs arising from geometric environments like visibility graphs of polygons, unit disk graphs, planar triangulations,... However, some of these classes are not well understood from a combinatorial point of view; for example, no combinatorial characterization of visibility graphs of polygons is known yet. Thus, we would like to also consider well understood classes of graphs that have interesting combinatorial properties: chordal graphs, interval graphs, intersection graphs of geometric objects,... Not only these classes share some properties with the geometric graphs we are interested in, but they also have interesting algorithmic properties that we may be able to use in order to design efficient distributed algorithms.

One goal is to identify graph classes where it is always possible for an agent to reconstruct a map of its environment, or where it is always possible to gather mobile agents that are initially scattered over the network. In this line of research, it was shown in [12] that an agent moving in the visibility graph of a simple polygon can always reconstruct a map of the underlying graph when it knows a bound on the size of the graph.

For specific graph classes, we are also interested in determining what initial information the agents need in order to solve these problems provided the underlying network belongs to the class. In order to obtain this kind of results, one should study closely the links between graph coverings and the combinatorial properties of the class in order to determine what are the combinatorial properties that can be detected in a distributed way.

For example, if we consider chordal graphs, it is easy to see that if an agent can identify simplicial vertices, then it can reconstruct a map of the graph, and several agents can always gather on a clique of the graph. Thus, one can ask how powerful the agent should be in order to identify the simplicial vertices of the graph.

Considering specific classes of graphs can also lead to the conception of specific algorithms that are more efficient than the ones existing for arbitrary graphs. A first step in this direction would be to design efficient exploration sequences using the combinatorial properties of these graph classes, since they can be subsequently use in map construction and rendezvous algorithms.

Agents with a local map. In the usual models considered in the literature, when located at a node of the network, an agent has a limited view of its environment: it can usually see the number of agents on its current position, the degree of this node and can distinguish the different outgoing links by their port numbers. There are also models [21, 35, 36] where agents can see the whole map of the network.

We would like to consider an intermediate model where the agent can see the graph induced by the neighbors of its current position: at each node the agent have a local map. If we go back to the example of chordal graphs, such an agent can easily identify simplicial vertices since it just has to check that the graph induced by its neighbors is a complete graph. In order to study this model, one has to use topological properties of the clique complex of the underlying graph. The clique complex of a graph G is an abstract simplicial complex where each clique of G is a simplex.

In [43], Mazurkiewicz introduce the class of locally derivable graphs; this large class of graphs enjoys nice properties that can be detected by a mobile agent with a local map. For instance, these graphs enjoys an elimination scheme where the rules to eliminate a vertex depends only on the graph induced by its neighborhood. In particular, this class contains all trees, all chordal graphs, and all cop-win graphs. However, no combinatorial characterization of locally derivable graphs has been provided, and it would be interesting to obtain such a characterization. One can show that in such graphs, agents with a local map can gather on a clique of the graph (i.e., they can solve weak rendezvous) even if they have no initial information about the graph. One can aim at identifying larger classes of graphs where weak rendezvous can be solved. It is easy to see that for any locally derivable graph, its clique complex is contractible. A natural question is to decide whether the contractibility of the clique complex is necessary and/or sufficient to solve weak rendezvous in this model.

In the classical model where an agent can only see its current position and cannot leave marks on nodes, if the agent has no information on the graphs, trees are the only graphs where exploration, map construction and weak rendezvous can be solved. If the agent has a local map, the classes of graphs where these three problems can be solved without any intial information are distinct. Our first goal is to characterize these classes using topological properties of the clique complex. We conjecture that the simple connectivity of the clique complex is necessary and sufficient to build a map of the environment, but we have no such clear ideas for the other problems. This model is interesting since the class of graphs that have a simply connected clique complex contains the chordal graphs, the visibility graphs of polygons and the planar triangulations. In other words, for the classes of graphs we mentionned above, we conjecture that it is always possible for a mobile agent with a local view to build a map of the graph even without any initial information about its environment.

Once we get characterizations of graphs where exploration, rendezvous, or map construction are solvable without initial information is solvable, we want to design efficient algorithms for these problems using the combinatorial and topological properties of these classes and the specificities of the model.

Delivrable: We plan to produce two deliverables for this task: a survey on relevant works in this area and a report describing the work done in the task.

Tâche 2/ Task 2: Geometric environments

Objectives: In this task, we will focus on distributed algorithms in geometric environments. The goal of this task is to study the impact of the sensing abilities of the mobile robots or the nodes of a sensors network on the performance of algorithms. A lot of works in mobile robots assume that the robot can sense perfectly the environment, i.e., it can see arbitrarily far and with accurate precision. Here, we will focus on robots with limited sensing and try to obtain efficient algorithms despite having much weaker assumptions. This objective is justified by the fact that real-life sensor are not accurate. Indeed, computer vision algorithms based on information obtained by sensors, such as stereo or structured-light finder, can reliably compute visibility scenes only up to a limited range [30].

Person in charge and involved members: Arnaud Labourel will be in charge of this task. Jérémie Chalopin, Shantanu Das and Emmanuel Godard will also be involved in this task, together with the PhD student funded by the project.

Detailed program, methods, technical choices and solutions:
Mobile robots in continuous models. Here, we consider mobile robots moving inside a polygonal environment. The robots can only see this environment up to a distance one (limited visibility). There is two interesting open questions we would like to study in this setting.

The first open problem is the competitiveness of exploration of polygons. To the best of our knowledge, the only paper to give a competitive online algorithm to explore polygons with limited sensing area is [19]. Unfortunately, this paper only deals with rectilinear polygons. The case of general polygons remains open and seems to be an interesting open question to study.

The second open problem is asynchronous rendezvous. For this problem, the robots can only choose its trajectory but not its speed. The speed of the robots is chosen at all time by an omniscient adversary that tries to prevent rendezvous (when the robots sees each other). It was proved that the rendezvous was feasible in this setting [20]. However, the complexity of the rendezvous algorithm has a cost at least exponential in the initial distance between the two robots. One might wonder if it is possible to obtain a polynomial cost. We conjecture that this is not possible and would like to work on a exponential lower bound.

Mobile robots in discrete models. An usual approach to deal with the complexity of continuous environment is to discretize it. Thus, we will consider graphs : grids, planar triangulations,... that discretizes the geometrical environment in which the robot is moving. This is a direct continuation of task 1 since we will study similar families of graphs, but with an important difference. Here, we will assume that the robot has some access to the embedding of the graph into the geometrical environment. For instance, the robot may be able to sense direction (compass), angles between edges, distances between node, coordinates,... This sensing capability will allow very efficient algorithms for exploration, map construction and rendezvous. In this area, two problems seem to be relevant and were recently studied by the community.

There are some interesting open problems for the simple robot model. For instance, when the robot can compute distances to visible vertices and can only move on the boundary of the polygon, is it possible to reconstruct the polygon? In this particular setting, the robot can see from its current vertex all distances to the visible vertices in clockwise order. The difficulty here is that the vertices seen by the robot are anonymous. Hence the robot does not know which vertex correspond to the distances measured. Another interesting open problem in this setting is exploration when the robot cannot retrace its movement, i.e., when it enters a node, it does not know the port number it arrives from. While reconstructing the graph is impossible for arbitrary graphs in this case, we conjecture that this is possible for visibility graphs.

Recent works in rendezvous [3, 15] assume that the robots knows their initial position and are fully aware of the topology of the networks. While these results obtained are interesting, the full knowledge of the network seems to be a very strong assumption. An interesting problem would be to consider embedded geometric graphs, such as planar graphs, in which robot can access at all time to its coordinates but does not know the exact topology of the graph. This may leads to similar results but with a much weaker assumption on the knowledge of the robot. Another interesting problem in this area would be to extend the results on grids for asynchronous rendezvous to more involved families of graphs such as planar triangulations. The work achieved in task 1 would give us the tools to better understand mobile robots in this families of graphs and solve this problem.

Local algorithms in locally aware networks. Local algorithms are distributed algorithms that run in constant number of rounds of communication. Being highly scalable and fault-tolerant, such algorithms are ideal for large-scale distributed systems. Several recent works on the subject have given local algorithms for non-trivial tasks (see [46] for a survey). However, some tasks are not computable in the deterministic setting. For instance, it is not possible to compute a constant approximation of a dominating set for unit disk graphs [40]. However, if the nodes of the networks are locally aware, i.e., know their coordinates, then a constant approximation can be computed in only one round of communication [50]. One might ask if this kind of results can be extended to other embedded geometric graphs such as planar triangulations or visibility graphs of polygons.

Delivrable: We plan to produce two deliverables for this task: a survey on relevant works in this area and a report describing the work done in the task.

Tâche 3/ Task 3: Dynamic networks

Objectives: In this part, we plan to investigate modeling and solving basic problems in highly dynamic networks with a mobile agents/mobile robots point of view. First we will investigate the fundamental problem of the dissemination of information in such dynamic networks. Then we will investigate modeling and solving mobile agents reachability problems in the model of time varying graphs. We also will try to characterize from a theoretical point of view the kind of dynamicity one could get when considering mobile robots (with a given bounded speed).

Person in charge and involved members: Emmanuel Godard will be in charge of this task. Jérémie Chalopin, David Ilcinkas, Arnaud Labourel and Pierre-Alain Reynier will also be involved in this task, together with Haitao Yuan and the postdoc funded by the project.

Detailed program, methods, technical choices and solutions:

Optimal broadcast in dynamic networks. The first model to consider will be the one of mobile faults. Given a graph (the underlying network) the behavior of the system is described, for example in the case of omission faults (losses of messages) exactly by a set of spanning subgraphs. In each round of the execution, one if these subgraphs corresponds to the communication event that occurs. Information will then propagate in the network depending on the properties of this subgraph. Here, the dynamic behavior comes from these omissions faults that occurs continuously. Interestingly, this model is also used in [39] to represent some dynamic networks, i.e., without a specific notion of failure. There is therefore a unifying property for these systems.

Hence, we will investigate such dynamic networks, where the topologie will evolve in time. These networks have been recently classified in terms of TVG "Time Varying Graphs" [9]. One of the question that occurs naturally in these networks is to minimize the number of transmitted message. Indeed, contrary to the first model were communication messages are *lost*, it is possible in these dynamic networks to know wether a message will be correctly received. Therefore, by a judicious choice of to which neighbours will a message be sent, it is possible to get an optimal broadcast time to the entire network while minimizing the number of transmitted bits. We will go from distributed computability problems to complexity problems. A part of the work will to thoroughly investigate the computability results according to the origin of the dynamicity of the network (faults, mobility, ...) using the classification of [9].

Dynamic networks and mobile robots. In this part, we plan to investigate the kind of dynamic networks one can obtain when considering mobile ad hoc networks that are generated by mobile robots. This kind of networks has already been investigated in the context of routing and lots of results have been obtained in this context (see e.g. from IETF [44]).

However, there has not been any investigation in the theoretical characterization of the kind of dynamic networks that can actually appear when mobile robots are considered. In the static case, a popular graph model for ad hoc networks is the *unit disk graph* model. We would to present and describe properties for *dynamic unit disk graph*, that is, what possible sequences of unit disk graphs are possible when we consider mobile robots with bounded speed.

The way such dynamic graphs will be geometrically embedded will also be investigated, in relation with task 2. We also plan to benefit in this study from the development of our simulator as described in Task 4b.

Mobile agents in dynamic networks. The previous studies are mainly oriented towards problems of dissemination of information (conditions about realizability, optimal algorithms) in dynamic networks. We would like to investigate the behavior of algorithms with mobile agents in dynamic networks. We will investigate accessibility problems for mobile agents and also the Rendezvous Problem.

The following approach will be used. First, we remark that the evolution of a mobile agent in such a dynamic system is very similar to the evolution of recognizability computation in a timed system. We would like to get ideas and techniques from the area of Timed Automata. First, a model must be defined to get a really appropriate model for dynamic networks. The Time Varying Graphs of [8] cannot be used without some adaption as for example the accessibility problem is undecidable in their framework. However, the model of timed automata is too restricted to be used as is. For example, dynamic network with periodic behavior are very important and interesting to study. However, getting periodicity in timed automata is actually not straightforward. Some work has been done [14] to extend the model to periodic timed automata (with guards on $\mathbb{Z}/n\mathbb{Z}$) but it is not possible to reuse the results from timed automata. The same techniques apply but the proofs have to be adapted.

One of our main objective is to adapt the very optimized techniques for reachability in timed automata (domain and zone algorithms for example) in order to get optimal algorithms for mobile agents.

Delivrable: We plan to produce two deliverables for this task: a survey on relevant works in this area and a report describing the work done in the task.

Tâche 4/ Task 4: Validation

This task regroups software related activities.

In subtask 4a, extensions of the ViSiDiA simulator for the study of models and algorithms introduced in Task 1, 2 and 3 will be implemented. The resulting simulator is intended for supporting the other tasks, but it's source code can be distributed under an open source licence, thus contributing to the visibility of the project.

In subtask 4b, « LED's CHAT », an actual distributed embedded system developed at LIF will serve as an application case study with the aim of extending the possibilities of this system by new algorithms derived from the projects work.

In subtask 4c, the potential interoperability of ViSiDiA with the « LED's CHAT » IDE will be studied.

Person in charge and involved members: Peter Niebert will be in charge of this task and coordinate subtask 4b. Emmanuel Godard will coordinate subtask 4a and 4c. Haitao YUAN and the postdoc funded by the project will participate in this task. Other members of the project will contribute on the conceptual level.

Risks: Peter Niebert could change the affiliation during the project, which could imply the need for third party conventions and additional travel cost for project meetings he attends.

Tâche 4a/ Task 4a: ViSiDiA and Dynamic Graphs

Objectives: The aim of this task is to implement a tool to help develop and visualize dynamic networks and mobile agents algorithms. This will allow to test for the algorithms proposed in the development of tasks 1, 2 and 3.

Detailed program, methods, technical choices and solutions: In the course of the studies involved by tasks 1, 2 and 3, we will develop and propose different mobile agents algorithms. It is both interesting and also a part of the evaluation of them to have them implemented. These implementations will serve both as testbed and proof of concept of our ideas.

We have chosen to base our code on the GraphStream framework [31]. It is a Java framework developed in the University of Le Havre. It is initiated and maintained by members of the RI2C research team from the LITIS computer science lab. The development was started in 2005 and the current stable release is 1.1. It is released under the CeCiLL C license.

The interest of this framework is twofold. First, it is a framework and not another graph library. Therefore it is possible to import from a wide variety of file formats. Second, it is highly event driven, this means that it is highly amenable to program algorithms both on static and dynamic graphs. Moreover, this framework has very interesting visualizations capabilities (output formats, video animations). We expect the overhead of reusing this framework to be very low, therefore enabling us to focus very easily on the mobile agent tools and algorithms. Moreover, some members of the team are already experienced in the development of a tool for visualization and simulation of distributed algorithms, ViSiDiA [49]. However ViSiDiA is lacking capabilities regarding dynamic properties of the underlying network, but part of its technology could probably also be reused.

It should be noted that, at this point, only graph algorithms have been developed in the GraphStream framework. Therefore introducing mobile agents algorithms to this framework will be an important contribution.

The code will hosted at the LIF facility : a software forge is already provided by our lab. It is based on `subversion` for version control and `trac` for management (milestones, issue tracking, ...)

Risks: The framework we have chosen is very stable and actively supported by the RI2C research team from the LITIS. Therefore there should be almost no risk in this concern. The main risk would be the lack of manpower to efficiently develop our tool. That is why it is expected that an important part of the CSC PhD student job will be on this development.

Delivrable: The main deliverable will be a component `gs.macaron` on top of Graph-Stream. This component will be used to develop and present some algorithms studied in task 1, 2 and 3.

Tâche 4b/ Task 4b: Dynamic « LED's CHAT »

Objectives: Motivated by « Marseille-Provence 2013, Capitale de la Culture Européenne », Peter Niebert of the LIF has invented a modular lightening system, which is of interest to this project. The modules of the system called « LED's CHAT » (`http://leds-chat.net/`) consist each of a microcontroller, sensors, LEDs and communication links to neighbouring modules. The tiles used for the 2013 event are equilateral triangles and can be connected to planar tilings but also to three dimensional surfaces called deltaedres. This is an example of a link between geometry and network topology. However, the particularity of « LED's CHAT » is the programming style derived from cellular automata, « cellular programming » : Each module executes the same program in a quasisynchronous manner, reads sensors, controls luminousity of LEDs and passes information to neighbours. There is a close integration of different layers, from data link up to application. Together with the geometric meaning of data links, « cellular programming » is an ideal application for the objectives of this project.

In addition to the actual hardware implementation, « LED's CHAT » also disposes of an integrated development environment with a simulator, which, in addition to being a case study for the purposes of this project, represents a nice vector for the visualisation of distributed algorithms. A publically funded exhibition during september-november 2013 in Marseille will feature an installation with several hundred modules. Moreover, LED's CHAT is subject to a technology transfer program with the aim of commercializing the technology to actual light applications.

In the current design, LED's CHAT requires a reboot when changing the topology and moreover, is limited to cabled data links. While the technology is fully scalable, big installations (buildings, streets) may require the addition and removal of modules during operation, as well as the integration of wireless links. In the project, we will thus study dynamic extensions of LED's CHAT, but also (ab)use LED's CHAT as a demonstrator for certain distributed algorithms. We will explore these extensions by extensions of the integrated development environment and also on the implementation recovered from the 2013 exhibition.

The resulting infrastructure allows to experiment with distributed algorithms in the simulator and to build demonstrators by combining the existing LED's CHAT prototype with communication modules acquired with means from the project.

Benefits for the project : The LED's CHAT application can result in an immediate technology transfer, since the transfer process is already started. On the other hand, the application has a natural « visibility » and can be useful for the communication about the actual objectives and aims of the project.

Detailed program, methods, technical choices and solutions: Concrete infrastructure tasks we will realise with LED's CHAT will include:

- Extension of the simulator to allow for a dynamic change of the topology;
- Integration of wireless links together with a failure model (unreliable communication);
- Development of embedded software for wireless communication modules (Zigbee) for the integration with LED's CHAT.

Based on this infrastructure, practical work based on the project's results can be implemented :

- Applications (running on the simulator as well as on the real system) to visualize distributed algorithms.
- Algorithms for dynamic addition and removal of modules.
- Algorithms for unreliable wireless links.

Delivrable: The deliverable consists of an extension of the existing code base of the integrated development environment and of a demonstrator based on LED's CHAT modules as well as the added wireless modules. This deliverable may be subject to technology transfer.

Tâche 4c/ Task 4c: Interoperability ViSiDiA - « LED's CHAT »

Detailed program, methods, technical choices and solutions: ViSiDiA is a general purpose visualization and simulation environment. The « LED's CHAT » project provides a Integrated Development Environment that offer also a simulation interface. Though quite specific to the « LED's CHAT » environment, this IDE share some features with ViSiDia. Most notably, it is intended to add dynamic behaviour capabilities to both of the simulator. Furthermore, « LED's CHAT » IDE could also gain from the graph editor UI of ViSiDiA.

In this subtask, the possibility of interoperability between those two project will be investigated. This interoperability study will be in two direction : the possiblity to use a common exchange format (for example for the graph topologies); the possibility to interact and run some « LED's CHAT » simulations in the ViSiDiA UI.

Tâche 5/ Task 5: Evaluation

Objectives: The aim of this task is the auto assessment of the progress achieved in the project and an evaluation of prospects arising from it. It is the dual of the survey that takes place in the first six months. It aims to establish a synthetic review of the project.

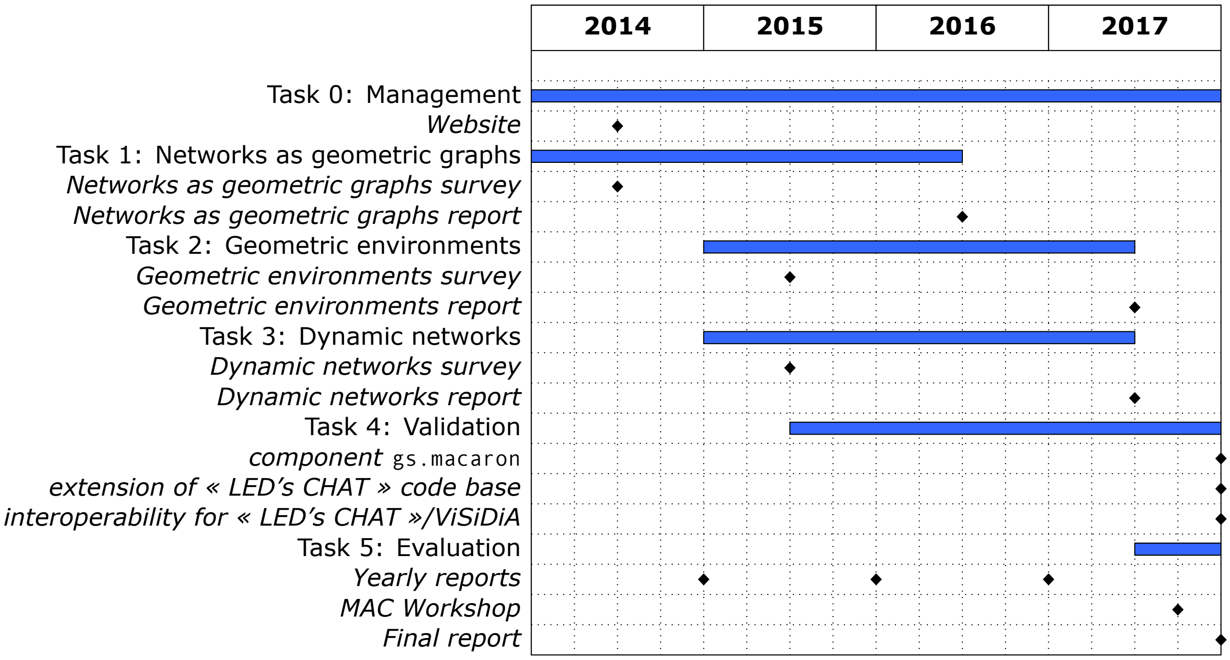
Person in charge and involved members: Jérémie Chalopin will be in charge of this task. All the other permanent members will be involved in this task.

Detailed program, methods, technical choices and solutions: The last six months of the project are concentrated on evaluation and the consolidation of tasks 1, 2, 3 and 4. All efforts in the last months of the project will be devoted to a synthetic analysis of the project. In a sense, this effort overlaps with all other tasks, except for the global perspective. In particular, we will analyze the successful and less successful aspects of our work and evaluate it in terms of scientific perspectives and (potential) applications.

In order to achieve objective review of the work done in the project, the tasks 1-4 will be evaluated by the participants less involved in them and discussed during several seminars of the project. In addition, we plan to organize a workshop at the end of the project. This workshop will be dedicated to mobile agents and robots and will be the follow-up of the MAC (Moving and Computing) workshop organized by Nicola Santoro and Paola Flocchini at Ottawa in 2010. This workshop would be a good occasion to have the opinions of experts in the domain on the work accomplished during the project

Delivrable: We plan to produce one deliverable for this task: the final report of the project. This report should be delivered soon after the end of the project, roughly 48 months after its start.

3.3. CALENDRIER / TASKS SCHEDULE



4. STRATÉGIE DE VALORISATION, DE PROTECTION ET D'EXPLOITATION DES RÉSULTATS / DISSEMINATION AND EXPLOITATION OF RESULTS, INTELLECTUAL PROPERTY

General valorization policy: The new Aix-Marseille University disposes of a Valorization Service that sets the general guidelines for the protection and valorization of intellectual property and technology transfer. The Laboratoire d'Informatique Fondamentale additionally disposes of a Valorization Cell, which includes Pierre-Alain Reynier and Peter Niebert. The purpose of this cell is to improve the laboratory effort in technology transfer and industrial relations. The project includes an application, « LED's CHAT », that is subject to an ongoing process of technology transfer: algorithms studied in the project may find their way into future products via this process.

Scientific communication: The project will disseminate the produced knowledge by presentations and publications in international workshops, conferences and journals, as usual for basic research. The budget for missions reflects the ambition in this area : We need to provide ourselves the means of international visibility. Submitted articles will be registered in the HAL data base to ensure protection of innovation claims. HAL will also serve as a reference to the produced publications in the project with an integration into the MaCARoN website.

Software development: The tools developed in the Task 4a and 4c are of academic level. We intend to publish versions of the tools under one of the CeCILL open source licenses, which allows to arouse interest in the academic community (and to obtain feedback from that community).

The code of « LED's CHAT » developed in Task 4b will be subject to an agreement with the copyright owner by the time of the project (currently, Aix-Marseille-University).

Scientific dissemination: The « LED's CHAT » system developed by Peter Niebert is a modular lightning system that can be used for scientific dissemination. A publicly funded exhibition during september-november 2013 in Marseille will feature an installation with several hundred modules, and there are already plans for future exhibitions of the system. These exhibitions can give a « visibility » to our project, and we can use them to present to the public the actual objectives of our project.

Creation of a new team: It is planned in the project of our laboratory (LIF) for the next five years that the subgroup of MoVe composed of Jérémie Chalopin, Shantanu Das, Emmanuel Godard and Arnaud Labourel will create a separate team from the group MoVe. The theme of the new team would be distributed algorithms. Emancipation as a team will permit us to gain international visibility in the scientific community.

MAC workshop: As stated in the description of task 5 we plan to organize a workshop of two days dedicated to mobile agents near the end of the project. This workshop will be dedicated to mobile agents and robots and will be the follow-up of the MAC (Moving and Computing) workshop organized by Nicola Santoro and Paola Flocchini at Ottawa in 2010. This will permit us to evaluate the results of the project and make our work known in the international community of distributed algorithms.

5. DESCRIPTION DE L'ÉQUIPE / TEAM DESCRIPTION

5.1. DESCRIPTION, ADÉQUATION ET COMPLÉMENTARITÉ DES PARTICIPANTS / PARTNERS DESCRIPTION & RELEVANCE, COMPLEMENTARITY

All members of the project except for David Ilcinkas are members of the MoVe research group in LIF in Marseille. The recruitments of Arnaud Labourel in september 2010 and of Shantanu Das in January 2013 together with the presence of Jérémie Chalopin and Emmanuel Godard have resulted in the creation of a small group working on distributed algorithms. David Ilcinkas is also an expert on distributed algorithms and has already collaborated with the people from LIF. Peter Niebert and Pierre-Alain Reynier are specialists of timed systems and they work mainly on verification problems. Recently, Peter Niebert has developed a modular lightening system called « LED's CHAT » which features several aspects of the networks studied in this project and which will serve as an application.

5.2. QUALIFICATION, RÔLE ET IMPLICATION DES PARTICIPANTS / QUALIFICATION AND CONTRIBUTION OF EACH PARTNER

• *Qualification du coordinateur de projet / Qualification of the proposal coordinator*

Jérémie Chalopin is responsible of the subgroup working on distributed algorithms within the MoVe research group at LIF.

He has already been involved in several research projects that are listed here:

- ANR ECSPER (2009–13): Étude et Conception de Systèmes avec Perturbations (ANR JCJC), coordinator: Pierre-Alain Reynier (LIF)
- ANR SHAMAN (2009–12): Self-organizing and Healing Architectures for Malicious and Adversarial Networks (ANR VERSO), coordinator: Sébastien Tixeuil (LIP6)
- ARC INRIA CaCO3 (2010–11): Calculs par Systèmes COntinus, COmplexes et Concurrents, coordinator: Mathieu Hoyrup (LORIA)
- Projet PHC Proteus (2010–11) with V. Chepoi (LIF), Y. Vaxès (LIF) and B. Bresar, Maribor University, Slovenia
- ANR RIMEL (2007–10): Raffinement Incrémental de Modèles événementiELs (ANR SETI), coordinator: Dominique Méry (LORIA)

He was highly implicated in these projects and participated to the redaction of activity reports and has thus a good knowledge of the management of projects.

• *Jérémie Chalopin*

Chargé de Recherche CNRS (Full time researcher), 32 years old

Cursus:
since 2007: Chargé de Recherche CNRS at LIF in the MoVe research group.
2003-06: PhD in Computer Science at LaBRI, Université Bordeaux 1 (Advisor: Y. Métivier)
2002-03: DEA Algorithmique , Université Paris 6
2000-02: Licence and Maîtrise in Computer Science, ENS Lyon

Research Interests: Distributed Algorithms, Graph Theory

Selected Publications:

- J. Chalopin, S. Das, Y. Disser, Matús Mihalák, Peter Widmayer. Mapping Simple Polygons: How Robots Benefit from Looking Back. *Algorithmica* 65(1): 43–59 (2013)
- J. Chalopin, E. Godard, Y. Métivier. Election in partially anonymous networks with arbitrary knowledge in message passing systems. *Distributed Computing* 25(4): 297–311 (2012)
- J. Chalopin, V. Chepoi, N. Nisse, Y. Vaxès. Cop and Robber Games When the Robber Can Hide and Ride. *SIAM J. Discrete Math.* 25(1): 333–359 (2011)
- J. Chalopin, S. Das. Rendezvous of mobile agents without agreement on local orientation. *ICALP 2010*: 515–526
- J. Chalopin, D. Gonçalves. Every planar graph is the intersection graph of segments in the plane: extended abstract. *STOC 2009*: 631–638

14 articles in international journals and 28 papers in international conference proceedings.

- *Shantanu Das*

Maître de conférences, chaire CNRS at Aix-Marseille Université (Assistant Professor), 33 years old

Cursus:
Jan. 2013-present: Maître de conférences, CNRS chair à Aix-Marseille Université. Member of the MoVe research group at LIF.
Oct. 2011-Dec. 2012: Postdoctoral Researcher at Ben-Gurion University and Technion-Israel Institute of Technology.
Jan. 2010-Aug. 2011: Postdoctoral Researcher at LIF and Aix-Marseille Université.
Mar. 2008-Dec. 2009: Post-doctoral Research Associate at Swiss Institute of Technology (ETH) with Professor Widmayer.
Jan. 2008-Feb. 2008: Research Associate, University of Ottawa, with Professor Nayak.
Sept. 2003-Dec. 2007: PhD in Computer Science at University of Ottawa (Advisor: A. Nayak and N. Santoro)
2003: Master degree in Computer Science, Indian Statistical Institute, India.

Research Interests: Distributed Algorithms, Mobile Robots and Optimization in Networks

Selected Publications:

- J. Chalopin, S. Das, Y. Disser, M. Mihalák, P. Widmayer: Mapping Simple Polygons: How Robots Benefit from Looking Back. Algorithmica 65(1): 43-59 (2013)
- S. Das, P. Flocchini, G. Prencipe, N. Santoro, M. Yamashita: The Power of Lights: Synchronizing Asynchronous Robots Using Visible Bits. ICDCS 2012: 506-515
- J. Chalopin, S. Das, Y. Disser, M. Mihalák, P. Widmayer: Telling convex from reflex allows to map a polygon. STACS 2011: 153-164
- J. Chalopin, S. Das, A. Labourel, E. Markou: Black Hole Search with Finite Automata Scattered in a Synchronous Torus. DISC 2011: 432-446
- S. Das, P. Flocchini, N. Santoro, M. Yamashita: On the computational power of oblivious robots: forming a series of geometric patterns. PODC 2010: 267-276

11 articles in international journals and 29 papers in international conference proceedings.

- *Emmanuel Godard*

Maître de conférences at Aix-Marseille Université (Assistant Professor), 39 years old

Cursus:
2011-present: Maître de conférences at Aix-Marseille Université. Member of the MoVe research group at LIF.
2010-11: Sabbatical: CNRS position at PIMS/*Simon Fraser University*
Jan.-Jul. 2010: Sabbatical (CRCT): visiting professor, *University of Victoria*
since 2003: Maître de conférences at Aix-Marseille Université. Member of the MoVe research group at LIF.
2002-2003: ATER at LIF, Aix-Marseille Université

2000-2002: PhD in Computer Science at LaBRI, Université Bordeaux 1 (Advisor: Y. Métivier)
Feb.-Jul. 2000: R&D Engineer (Cryptography) at *FinGO* (mobile finance start-up)
Sept. 1998-Feb. 2000: National Service.
1997-1998: Starts of PhD in Computer Science, Bordeaux University
1996-1997: Agrégation de Mathématiques
1995-1996: DEA Algorithmique Université Paris 7

Research Interests: Distributed Algorithms, Visualization and Simulation, Modeling

Selected Publications:

- J. Chalopin, E. Godard, and Y. Métivier. Election in partially anonymous networks with arbitrary knowledge in message passing systems. *Distributed Computing* 25(4): 297-311 (2012)
- V. Chepoi, T. Fevat, E. Godard, and Y. Vaxès. A self-stabilizing algorithm for the median problem in partial rectangular grids and their relatives. *Algorithmica* 62(1-2): 146-168 (2012)
- E. Godard and J. Peters. Consensus vs broadcast in communication networks with arbitrary mobile omission faults. SIROCCO 2011: 29–41.
- T. Fevat and E. Godard. Minimal obstructions for the coordinated attack pr oblem and beyond. IPDPS 2011: 1001–1011.
- J. Chalopin, E. Godard, Y. Métivier: Local Terminations and Distributed Computability in Anonymous Networks. *DISC 2008*: 47–62

7 articles in international journals and 11 papers in international conference proceedings.

- *Arnaud Labourel*

Maître de conférences at Aix-Marseille Université (Assistant Professor), 31 years old

Cursus:
since 2010: Maître de conférences à Aix-Marseille Université. Member of the MoVe research group at LIF.
2009-10: ATER at LaBRI, Université Bordeaux 1
2008-09: Post-doctoral student at UQO with Professor Pelc.
2007-08: ATER at LaBRI, ENSEIRB
2004-07: PhD in Computer Science at LaBRI, Université Bordeaux (Advisor: C. Gavoille)
2003: Master degree in Computer Science at Université Bordeaux

Research Interests: Distributed algorithms, Graph Theory

Selected Publications:

- J. Czyzowicz, A. Labourel and A. Pelc. How to meet asynchronously (almost) everywhere. ACM Transactions on Algorithms 8(4): 37 (2012)
- J. Chalopin, S. Das, A. Labourel and E. Markou. Black Hole Search with Finite Automata Scattered in a Synchronous Torus. DISC 2011: 432-446.
- J. Czyzowicz, A. Labourel and A. Pelc. Optimality and competitiveness of exploring polygons by mobile robots. Inf. Comput. 209(1): 74-88, 2011.

- E. Bampas, J. Czyzowicz, L. Gasieniec, D. Ilcinkas and A. Labourel. Almost Optimal Asynchronous Rendezvous in Infinite Multidimensional Grids. DISC 2010: 297-311.
- J. Czyzowicz, D. Ilcinkas, A. Labourel, A. Pelc. Optimal Exploration of Terrains with Obstacles. SWAT 2010: 1-12.

8 articles in international journals and 13 papers in international conference proceedings.

• *Peter Niebert*

Maître de Conférences (assistant professor), 46 years old

Cursus:
2011: Habilitation à diriger des recherches, Université de Provence
since 2000: Maître de Conférences at LIF in the MoVe research group.
1998-2000: postdoc at VERIMAG (Grenoble)
1992-1997 PhD in Computer Science in Hildesheim, Germany

Research Interests: Model Checking and related methods, embedded systems

Selected Publications:

- J. Malinowski and P. Niebert and P.-A. Reynier, A Hierarchical Approach for the Synthesis of Stabilizing Controllers for Hybrid Systems, *Automated Technology for Verification and Analysis ATVA*, lncs 6996,198-212, 2011
- J. Malinowski and P. Niebert, SAT based Bounded Model Checking with Partial Order Semantics for timed automata, in *TACAS*, lncs 6015, 405-419, 2010
- D. Peled and P. Niebert, Efficient model checking for LTL with partial order snapshots, *Theoretical Computer Science (Elsevier)*, 410 (42), 4180-4189, 2009.
- P. Niebert, D. Peled, and A. Pnueli, Discriminative model checking, in *the 20th Computer Aided Verification (CAV)*, pages 504–516, 2008.
- D. Lugiez, P. Niebert and S. Zennou, A partial order semantics approach to the clock explosion problem, *Theoretical Computer Science (Elsevier)*, 345 (1),27-59, 2005.

3 articles in international journals and 25 papers in international conference proceedings.

• *Implications dans d'autres projets/Involvement in other projects*

We indicate here the recent projects in which the members of our team are, or have been involved recently.

Nom/Name	Implication (PM)	Projet / Project	Coordinateur / Coordinator	Dates
J. Chalopin P. Niebert P.-A. Reynier	16 24 36	ECSPER (ANR JCJC), 269 306€	P.-A. Reynier	2009–2013
J. Chalopin E. Godard	19,2 19,2	SHAMAN (ANR VERSO), 818 464 €	S. Tixeuil	2009–2012
E. Godard	12	PANDA (ANR Blanc), 576 000 €	C. Palamidessi	2009–2012
D. Ilcinkas	36	DISPLEXITY (ANR Blanc), 730 000€	C. Delporte-Gallet	2012–2015
D. Ilcinkas	4	EULER (FP7 STREP), 200 000€ (for LaBRI)	D. Papadimitriou	2010–2013

6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDÉS / SCIENTIFIC JUSTIFICATION OF REQUESTED RESSOURCES

Globally, including non permanent staff funded by the project (48 person.months), we obtain 216 person.months for the four years of the project, which corresponds to 4,5 full-time researchers per year. We use this number to evaluate further costs.

- *Personnel / Staff*

For the realization of the project two non-permanent employees, we would like to hire one PhD student (three years) and one post-doctoral researcher (one year).

PhD student: The aim of the project is a perfect fit for a PhD thesis in theoretical computer science. Most of the work that would be achieved in the project will be fundamental research. As specified in the description of tasks in section 3, the PhD student will be involved in most of the tasks of the project (tasks 1, 2, 3 and 4). The exact implication of the PhD student in each of these tasks will depend on his skills and aspirations. In order to decide quickly the exact involvement of the student in each task, we would like to hire a PhD student quickly after the beginning of the project. This involvement seems essential for the PhD thesis and the integration of the student in the project.
Estimated cost: 88,2K€

Post-doctoral researcher: A large part of our work will be devoted to the study of dynamic systems and applications (task 3 and 4). These aspects will mainly be focused on during the third and fourth years of the project. This will be a period of high activity, and we would like to hire a post-doctoral researcher during this period, either on third or on four year depending on the candidates and on the advancement of the project. The post-doctoral researcher would thus be concerned mainly by dynamic system models and implementation of tools related to these models.
Estimated cost: 42K€

- *Missions / Travel*

As for any fundamental research project, this is very important to have national and/or international relations and collaborations. Moreover, we also plan to go to international workshop and conferences to present our works and exchange with other researchers. Therefore, we need fundings for national and international travels. Considering that a full-time researcher may have two international missions per year plus national missions, we evaluate the missions expenses to 4K€ per year and per full-time researchers.
Estimated cost: 4,5 $\times$ 4 $\times$ 4K€ = 72K€

We think that having visits of external senior researchers every year will be beneficial to the project. We would like to invite colleagues we already collaborate with, as well as other specialists in order to initiate new collaborations. Among our current collaborators, we would like to invite Jurek Czyzowicz (Université du Québec en Outaouais), Paola Flocchini (University of Ottawa), Andrzej Pelc (Université du Québec en Outaouais), Nicola Santoro (Carleton University) and Peter Widmayer (ETH Zürich). With the cost of the travel, we evaluate the cost of a one week visit in Marseille to 1.5 k€. We plan to invite external people for 3 weeks a year.
Estimated cost: 4 $\times$ 3 $\times$ 1.5K€ = 18K€

In order to collaborate efficiently, we believe that David Ilcinkas has to come regularly to Marseille. We plan one or two weeks each year.
Estimated cost: 6K€

- *Dépenses sur facturation interne / Expenses with internal billing*

For teaching compensations (96 hours per year), we ask, as specified in the document presenting rules of the "ANR JCJC" projects, an amount of 10K€ per year.
Estimated cost: 40K€

- *Autres dépenses de fonctionnement / Other expenses*

First, we need personal computers for the different members of the project. We evaluate that the life-time of such a computer is of four years, and thus ask for 4,5 personal equipments. We evaluate the cost of such an equipment to 2500€ (laptop plus external display).
Estimated cost: 4,5 $\times$ 2,5K€ = 11.25K€

Second, for the « LED's CHAT » project, we would like to build a prototype of wireless modules. To do so, we need to get some specific components to handle wireless communication.
Estimated cost: 2K€

Third, we would like to hire master students for internships (3 $\times$ 6 months).
Estimated cost: 3 $\times$ 6 $\times$ 500€ = 9K€

Fourth, we have mentioned in the description of the Task 5 on overall evaluation our objective to organize a workshop of two days dedicated to mobile agents. We ask for this workshop a financiary help of 6K€.
Estimated cost: 6K€

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Laboratoire d'informatique fondamentale de Marseille (LIF)

UMR 7279 Université d'Aix-Marseille - CNRS

Objet : lettre d'intention pour le soutien du projet Macaron en réponse à l'appel ANR JCJC 2013

Marseille, le mercredi 16 janvier 2013

Madame, Monsieur,

Je, soussigné Jean-Marc Talbot, directeur du Laboratoire d'Informatique Fondamentale (LIF UMR7279 AMU & CNRS) m'engage à soutenir le projet Macaron par mise à disposition de locaux, de moyen humains et d'accès au matériel nécessaire à la réalisation des objectifs scientifiques de projet, dans le cas de l'obtention d'un financement par l'ANR (appel JCJC 2013).

Ce soutien est conforme au projet du laboratoire qui souhaite voir se développer et se structurer au sein du LIF la thématique "algorithmique distribuée".

Jean-Marc Talbot
Directeur du LIF

Laboratoire d'Informatique Fondamentale de Marseille UMR 7279 Université d'Aix-Marseille – CNRS
Parc Scientifique et Technologique de Luminy 163, avenue de Luminy - F-13288 Marseille Cedex 9
Tel : +33 (0)4 91 82 90 70 / 94 95 Fax : +33 (0)4 91 82 92 www.lif.univ-mrs.fr