INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team dnet

Dynamic Networks

Grenoble - Rhône-Alpes

Theme : Networks and Telecommunications

Activity Report

2010

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D-NET is a common project with CNRS, ENS de Lyon, Université Claude Bernard Lyon 1.

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2. Overall Objectives

2.1. Overall Objectives

The main goal of the D-NET team is to lay solid foundations to the characterization of dynamic networks, and to the field of dynamic processes occurring on large scale interaction networks. In order to develop tools of practical relevance in real-world settings, we propose to ground our methodological studies on real data sets obtained through large scale in situ experiments.

Let us consider the example of health science and public health policy. The spread of infectious diseases remains an urgent public health issue. All spreading models validity crucially depend on our ability to understand and describe the interactions among individuals in the population. Building this knowledge requires the availability of individuals interaction records. Only recently it has become possible to study large scale interaction networks, such as collaboration networks, e-mail or phone call networks, sexual contacts networks, *etc.* This has prompted many research efforts in complex network science, mainly in two directions. First, attention has been paid to the network structure, considered as static graphs. Second, a large amount of work has focused on the study of spreading models in complex networks, which has highlighted the role of the network topology on the dynamics of the spreading. However, the dynamics of the networks, *i.e.*, topology changes, and in the networks, *e.g.*, spreading processes, are still generally studied separately. There is therefore an important need developing tools and methods for the joint analysis of both dynamics.

The D-NET project emphasizes the cross fertilization between these two research lines which should definitively lead to considerable advances. The D-NET project has the following fundamental goals:

1. To develop distributed measurement architectures based on sensor networks in order to capture physical phenomena in space and time;
2. To develop the study of dynamic interaction networks, through the design of specific tools targeted at characterizing and modeling their dynamic properties.
3. To study dynamic processes occurring in dynamic networks, such as spreading processes, taking into account both the dynamics of and in the network structure.
4. To apply these theoretical tools to large scale experimental data sets.
5. to set up and foster multidisciplinary collaborations in order to study these interaction networks in their original context.

Most activity on complex networks has up to now focused on static networks, the characterization of their structure, and the understanding of how their structure influences dynamic processes such as spreading phenomenon. The important step that the D-NET project wants to undertake is to consider that the networks themselves are dynamic entities. Their topologies evolve and adapt in time, possibly driven by or in interaction with the dynamic process unfolding on top of it. Measuring this dynamic is now affordable mainly thanks to the deployment of sensor networks that can be deployed close to the physical interacting objects. As an example, in the MOSAR context, sensors measure contacts between individuals. The resulting data set is an opportunity to develop analysis methods and tools directly connected to real-world situations and adapted to the specific context from where the data set is issued. Still in the MOSAR context, a better understanding of dynamic processes on dynamic interaction networks should help the development of appropriate response measures and protocols to the spreading of AMRB.

The D-NET project therefore addresses both very fundamental and very applied aspects that are tightly linked. On one hand, to develop knowledge in the networking field, in order to provide a better understanding of dynamic graphs. This fundamental work is grounded on real world large scale dynamic networks. On the other hand, to help develop a better understanding of the physical objects and networks that are studied. This point requires the joint study of both dynamics of the network and in the network, and requires a tied collaboration with the research disciplines where the objects come from.

The impact of the research developed in D-NET goes beyond the context of disease spreading studied within the MOSAR context, thanks to the inherent interdisciplinary of the complex networks research field. Dynamic processes on dynamic networks are indeed present in numerous fields, including rumor spreading in social networks, opinion formation, fashion phenomena, the innovation diffusion in a population, *etc.* The spread of computer viruses may take place through email networks or bluetooth connections, which are both dynamical. The development of efficient algorithms for information spreading in wireless/P2P/DTN networks should also be improved by the understanding of the dynamics of these networks and their temporal properties. The study of all these processes should benefit from the tools developed in this project. It represents an important opportunity to study real-world dynamic processes occurring on interaction networks whose dynamics can be measured.

2.2. Highlights

MdS 2010 Human and scientific challenge for the xtremlog project consisting in a complete data logging of a runner during the *25th marathon des sables*. A self sufficient race in the desert during 7 days and 250km. G. Chelius overcome the desert hell in 32h10, finishing at the 66th position over 1090 participants.

SensLAB 1024 wireless sensor nodes have been launched in beta test in 2010. The national SensLAB platform will be officially open beginning of 2011. No not mis s the movie explaining the objectives and challenges os SensLAB. and the ANR FLAB project granted in 2010 will allow to connect the world of communicating objects (SensLAB) to the Future Internet (OneLAB).

3. Scientific Foundations

3.1. Sensor network, distributed measure and distributed processing

Participants: Guillaume Chelius, Eric Fleury, Andreea Chis, Loïc Lemaître, Clément Burin des Rosiers, Sandrine Avakian, Guillaume Roche, Jean-Pierre Poutcheu, Fabien Jammes.

Glossary

Sensor network for distributed embedded measure. In order to gather information on the dynamic of a specific physical phenomena, a distributed embedded measure must be performed. The quality of the measure is crucial and largely impacts the analysis. Moreover, by conducing and controlling the measure and its bias during the experiment, one may adapt and optimize the analysis.

Sensors networks offer an efficient way to measure physical phenomena at various space and time scales. The important challenge is to take advantage of a communicating sensor node that can be associated to a physical object in order to design a large scale distributed measurement system that can monitor and sense the physical world. Given a target application, the goal is to design adequate sensor nodes and to set up the way they communicate, cooperate and collect their data in order to fulfill the application constraints. Fulfilling this goal requires the development of theoretical and practical techniques to help the dimensioning and deployment of such distributed sensing tools, to manage the distributed measures and to perform efficient and reliable distributed computing on top of the network. With these main tasks in mind, we define the following objectives:

Design of a global sensing tool. Based on the deployment context, we should propose a methodology to design the most appropriate and accurate measurement architecture that matches the application constraints. Heterogeneity is a fundamental, beneficial quality of distributed sensing tool, not just a problem to overcome. Heterogeneous sensing systems are more immune to the weaknesses of sensing modalities and more robust against defective, missing, or malicious data sources than even carefully designed homogeneous systems. However, data heterogeneity also presents main challenges when trying to integrate data from many different sensors.

Measure characterization and dimensioning. Measure characterization and dimensioning must take into account the different correlations in space and time that exist between all sensors. It must also handle the various time scales that may exist in the measures. The challenge is due to the heterogeneous data resolution. Moreover, data is generally multi modal and multi scale with possible irregularities and offer much correlation in time and/or space. Data sets collected by various sensors may be characterized by the lack of most common simple statistical properties such as stationary, linearity, or Gaussianity. Relevant time scales may be difficult to identify, or may even not exist. Observed properties have non-trivial relations and even the choice of the time scale granularity that should be used in the measure and the analysis is a complex problem as it may bias the analysis in an uncontrolled way.

In-network distributed processing. As some computation can be delocalized closer to the sensed phenomena, in the sensor nodes, space/time correlations can be exploited in order to optimize the amount of data sent through the network.

3.2. Statistical Characterization of Complex Interaction Networks

Participants: Guillaume Chelius, Eric Fleury, Adrien Friggeri.

Glossary

Evolving networks can be regarded as "*out of equilibrium*" systems. Indeed, their dynamics is typically characterized by non standard and intricate statistical properties, such as non-stationarity, long range memory effects, intricate space and time correlations.

The dynamics of complex networks often exhibit no preferred time scale or equivalently involve a whole range of scales and are characterized by a scaling or scale invariance property. Another important aspect of network dynamics resides in the fact that the sensors measure information of different nature. For instance, in the MOSAR project, inter-individual contacts are registered, together with the health status of each individual, and the time evolution of the resistance to antibiotics of the various strains analyzed. Moreover, such information is collected with different and unsynchronized resolutions in both time and space. This property, referred to as multi-modality, is generic and central in most dynamical networks. With these main challenges in mind, we define the following objectives.

From "primitive" to "analyzable" data: Observables. The various and numerous modalities of information collected on the network generate a huge "*primitive*" data set. It has first to be processed to extract "*analyzable data*", which can be envisioned with different time and space resolutions: it can concern either local quantities, such as the number of contacts of each individual, pair-wise contact times and durations, or global measures, *e.g.*, the fluctuations of the average connectivity. The first research direction consists therefore in identifying, from the "primitive data", a set of "analyzable data " whose relevance and meaningfulness for the analysis of network dynamic and network diffusion phenomena will need to be assessed. Such " analyzable data " needs also to be extracted from large " primitive data " set with " reasonable " complexity, memory and computational loads.

Granularity and resolution. The corresponding data will take the form of time-series, "condensing" network dynamics description at various granularity levels, both in time and space. For instance, the existence of a contact between two individuals can be seen as a link in a network of contacts. Contact networks corresponding to contact sequences aggregated at different analysis scales (potentially ranging from hours to days or weeks) can be built. However, it is so far unclear to which extent the choice of the analysis scale impacts the relevance of network dynamics description and analysis. An interesting and open issue lies in the understanding of the evolution of the network from a set of isolated contacts (when analyzed with low resolution) to a globally interconnected ensemble of individuals (at large analysis scale). In general, this raises the question of selecting the adequate level of granularity at which the dynamics should be analyzed. This difficult problem is further complicated by the multi-modality of the data, with potentially different time resolutions.

(non-)Stationarity. Stationarity of the data is another crucial issue. Usually, stationarity is understood as a time invariance of statistical properties. This very strong definition is difficult to assess in practice. Recent efforts have put forward a more operational concept of relative stationarity in which an observation scale is explicitly included. The present research project will take advantage of such methodologies and extend them to the network dynamics context.

The rationale is to compare local and global statistical properties at a given observation scale in time, a strategy that can be adapted to the various time series that can be extracted from the data graphs so as to capture their dynamics. This approach can be given a statistical significance via a test based on a data-driven characterization of the null hypothesis of stationarity.

Dependencies, correlations and causality. To analyze and understand network dynamics, it is essential that (statistical) dependencies, correlations and causalities can be assessed among the different components of the " analyzable data ". For instance, in the MOSAR framework, it is crucial to assess the form and nature of the dependencies and causalities between the time series reflecting e.g., the evolution along time of the strain resistance to antibiotics and the fluctuations at the inter-contact level. However, the multimodal nature of the collected information together with its complex statistical properties turns this issue into a challenging task. Therefore, Task1 will also address the design of statistical tools that specifically aim at measuring dependency strengths and causality directions amongst mutivariate signals presenting these difficulties. The objective is to provide elements of answers to natural yet key questions such as : Does a given property observed on different components of the data result from a same and single network mechanism controlling the ensemble or rather stem from different and independent causes? Do correlations observed on one instance of information (e.g., topological) command correlations for other modalities? Can directionality in correlations (causality) be inferred amongst the different components of multivariate data. These should also shed complementary lights on the difficulties and issues associated to the identification of "important" nodes or links...

3.3. Theory and Structural Dynamic Properties of dynamic Networks

Participants: Guillaume Chelius, Christophe Crespelle, Eric Fleury, Qinna Wang.

Glossary

Characterization of the dynamics of complex networks. We need to focus on intrinsic properties of evolving/dynamic complex networks. New notions (as opposed to classical static graph properties) have to be introduced: rate of vertices or links appearances or disappearances, the duration of link presences or absences. Moreover, more specific properties related to the dynamics have to be defined and are somehow related to the way to model a dynamical graph.

To go further in the Classical graph notions like the definition of path, connected components and k-core have to be revisited in this context. Advanced properties need also to be defined in order to apprehend the intrinsic dynamic structural issues of such dynamic graphs. The notion of communities (dense group of nodes) is important in any social / interaction network context and may play an important role within an epidemic process. To transpose the static graph community concept into the dynamical graph framework is a challenging task and appears necessary in order to better understand how the structure of graphs evolves in time. In these context we define the following objectives:

Toward a dynamic graph model and theory. We want to design new notions, methods and models for the analysis of dynamic graphs. For the static case, graph theory has defined a vast and consistent set of notions and methods such as degrees, paths, centrality measures, cliques. These notions and methods are completely lacking for the study of dynamic graphs; not only do we not have basic notions allowing the description of a graph and its dynamics, but we also lack the basic definitions and algorithms for manipulating dynamic graphs. Our goal is therefore to fill this lack, by providing the basic notions for manipulating dynamic graphs as well as the notions and indicators to describe its dynamic meaningfully (as complex networks theory does for static complex networks).

Dynamic communities. The detection of dynamic communities is particularly appealing to describe dynamic networks. In order to extend the static case, one may apply existing community detection methods to successive snapshots of dynamic networks. This is however not totally satisfying for two main reasons: first, this would take a large amount of time (directly proportional to the data span); moreover, having a temporal succession of independent communities is not sufficient and we loose valuable information and dependencies. We also need to investigate the temporal links, study the time granularity and look for time periods that could be compressed within a single snapshot.

Tools for dynamic graph visualization. Designing generic and pure graph visualization tools is clearly out of the scope of the D-NET project. Efficient graph drawing tools or network analysis toolkit/software are now available (e.g., GUESS, TULIP, Sonivis, Network Workbench). However, the drawback of most softwares is that the dynamics is not taken into account. Since we will study the hierarchy of dynamics through the definition of communities we plan to extend graph drawing methods by using the communities' structures. We also plan to handle the time evolution in the network analysis toolkit. A tool like TULIP is well designed and could be improved by allowing operations (selection, grouping, sub graph computation...) to take place on the time dimension as well.

4. Application Domains

4.1. Life Science & Health

In parallel to the advances in modern medicine, health sciences and public health policy, epidemic models aided by computer simulations and information technologies offer an increasingly important tool for the understanding of transmission dynamics and of epidemic patterns. The increased computational power and use of Information and Communication Technologies makes feasible sophisticated modeling approaches augmented by detailed in vivo data sets, and allow to study a variety of possible scenarios and control strategies, helping and supporting the decision process at the scientific, medical and public health level. The research conducted in the D-NET project finds direct applications in the domain of LSH since modeling approaches crucially depend on our ability to describe the interactions of individuals in the population. In the MOSAR project we are collaborating with the team of Pr. Didier GUILLEMOT (Inserm/Institut. Pasteur/Université de Versailles). Within the TUBEXPO project, we are collaborating with Pr. Jean-Christopge Lucet (Professeur des universités Paris VII – Praticien hospitalier APHP).

4.2. Complex networks

In the last ten years, the study of complex networks has received an important boost with large interdisciplinary efforts aimed at their analysis and characterization. Two main points explain this large activity: on the one hand, many systems coming from very different disciplines (from biology to computer science) have a convenient representation in terms of graphs; on the other hand, the ever-increasing availability of large data sets and computer power have allowed their storage and manipulation. Many maps have emerged, describing many networks of practical interest in social science, critical infrastructures, networking, and biology. The D-NET project targets the study of dynamically evolving networks, from the point both of their structure and of the dynamics of processes taking place on them.

4.3. Biologging

The research conducted in the D-NET project finds direct applications in the domain of bio-logging. Bio-logging consists in equipping animals with tracking and sensing devices such that its mobility, environmental conditions and social interactions can be monitored. In the Dispop project and in collaboration with the DEPE of the IPHC, the D-NET project is active in the biologging field, more particularly on three principal topics : the design of efficient sensing devices, also called biologgers, the conception of a generic trajectometry software and the design of analytical tools for the study of social interactions in an animal population.

4.4. Biomechanics, physiology and sport

The research conducted in the D-NET project finds direct applications in the domains of bio-mechanics, physiology and sport. In the context of the SensTools project, the D-NET has contributed to the design of a distributed multi-sensor architecture that can be worn by an individual and that records bio-mechanical, physiological and environmental data. The deployment of this architecture took place during the 25th Marathon des Sables.

5. Software

5.1. WSNet

Participant: Guillaume Chelius [correspondant].

WSnet is a wireless sensor network simulator that was designed to offer the following features:

- a modular, flexible and accurate simulation of the radio physical medium;
- support for the simulation of environmental phenomena;
- support for interaction between nodes and their environment (sensor-actuator architecture);
- interconnection with the sensor platform emulator WSim to support the distributed emulation of wireless sensor networks.

WSNet is currently in its second release. The number of WSNet users is still growing and several research works reference the software. Many pointers can be found on the project website. Maintenance and support of the software is handled by the D-NET project but also by several contributors from the CITI laboratory (INSA de Lyon), Orange R&D. The WSNet community is quietly spreading in France as well as abroad.

5.2. WSNet-3

Participants: Loïc Lemaître, Guillaume Chelius [correspondant].

Driven by the feedback gathered among WSNet users, we have started the development of the third WSNet release. While still private, the project web page is available. The objectives behind this new development is:

- to ease the simulation of new radio architectures / standards : *e.g.* MIMO schemes, UWB, multi-interfaces system;
- to ease the writing of new modules through the use of *High Level Languages* such as Python or Ruby for the development of protocols, *etc* ;
- to ease the debugging and compilation of results during a simulation.

These developments are handled by a core of developers from different affiliations (INSA de Lyon, Orange R&D, INRIA) lead by the D-NET team.

5.3. WSIM

Participants: Eric Fleury, Loïc Lemaître, Guillaume Chelius, Antoine Fraboulet [correspondant].

WSim is a platform simulator. It relies on cycle accurate full platform simulation using microprocessor instruction driven timings. The simulator is able to perform a full simulation of hardware events that occur in the platform and to give back to the developer a precise timing analysis of the simulated software.

The native software of the node can be used in the simulator without the need to reconfigure or recompile the software. We use a classical GCC cross-compiler toolchain and the simulation is not attached to any particular language nor operating system. We are thus able to debug and evaluate performances of the full system at the assembly level. A precise estimation of timings, memory consumption and power can be obtained during simulation. FreeRTOS, Contiki and TinyOS operating systems have been successfully tested on simulation platforms.

The simulator can be used in standalone mode for debuging purposes when no radio device is used in the design (or when the radio simulation is not needed). But one of the main WSim feature is its interface with the WSNet simulator to perform the simulation of a complete sensor network.

See also the http://wsim.gforge.inria.fr/ web page.

- Version: 0.9
- ACM: C.2.2: Computer- Communication Networks; D.2.5: Testing and Debugging–Debugging aids, Monitors; D.2.6:Programming Environments–Integrated environments
- Keywords: embedded software, simulation, debugging, energie optimization
- Software benefit: existing coupling with WSNET
- APP: IDDN 06-370012-000
- License: CeCILL (2)
- Type of human computer interaction: Console, interface graphique Win32 / X11 / libSDL
- OS/Middelware: Unix (Linux, BSD), Windows, MacOSX
- Programming language: Langage C

5.4. WSN430 hardware

Participants: Eric Fleury, Guillaume Chelius, Clément Burin des Rosiers, Guillaume Roche.

As a outcomes of the ANR SensLAB project and the INRIA ADT SensTOOLS, several hardware modules and daughter cards were delivered and made available to the research community. One goal is to provide both generic and specialized sensor boards (GPS accelerometer, Test, Strain, Bluetooth, Motion capture, Heart rate) in order to span a large class of sensor network applications.

All the hardware designed are gathered under the SensLAB web site: http://www.senslab.info/ and all are released under a creative common license.

5.5. Sensor Network Tools: drivers, OS and more

Participants: Guillaume Chelius, Eric Fleury [correspondant], Clément Burin des Rosiers, Sandrine Avakian, Guillaume Roche, Jean-Pierre Poutcheu, Guillaume Chelius.

As a outcomes of the ANR SensLAB project and the INRIA ADT SensTOOLS, several softwares (from low level drivers to OSes) were delivered and made available to the research community. The main goal is to lower the cost of developing/deploying a large scale wireless sensor network application. All software are gathered under the SensLAB web site: http://www.senslab.info/ web page where one can find:

- low C-level drivers to all hardware components;
- ports of the main OS, mainly TinyOS, FreeRTOS and Contiki;
- ports and development of higher level library like routing, localization.

6. New Results

6.1. Tuberculosis exposition: reconstructing the social interactions using Wireless Sensor Network

In the very active field of complex networks, research advances have largely been stimulated by the availability of empirical data and the increase in computational power needed for their analysis. These works have led to the identification of similarities in the structures of such networks arising in very different fields, and to the development of a body of knowledge, tools and methods for their study. While many interesting questions remain open on the subject of static networks, challenging issues arise from the study of dynamic networks. In particular, the measurement, analysis and modeling of social interactions are first class concerns. In [2] and in [15], [12] we address the challenges of capturing physical proximity and social interaction by means of a wireless network. In particular, as a concrete case study, we exhibit the deployment of a wireless sensor network applied to the measurement of Health Care Workers' exposure to tuberculosis infected patients in a service unit of the Bichat-Claude Bernard hospital in Paris, France. This network has continuously monitored the presence of all HCWs in all rooms of the service during a 3 month period. We both describe the measurement system that was deployed and some early analysis on the measured data. We highlight the bias introduced by the measurement system reliability and provide a reconstruction method which not only leads to a significantly more coherent and realistic dataset but also evidences phenomena a priori hidden in the raw data. By this analysis, we suggest that a processing step is required prior to any adequate exploitation of data gathered thanks to a non-fully reliable measurement architecture.

6.2. Dynamic network model

In [11], we propose a framework for the study of dynamic mobility networks. We address the characterization of dynamics by proposing an in-depth description and analysis of two real-world data sets. We show in particular that edges creation and deletion processes are independent of other graph properties and that such networks exhibit a large number of possible configurations, from sparse to dense. From those observations, we propose simple yet very accurate models that allow to generate random mobility graphs with similar temporal behavior as the one observed in experimental data.

In [1] we we study another dynamic complex network coming from community shared bicycle systems, namely the Vélo'v program launched in Lyon in May 2005. Such a network is a public transportation programs that can be studied as a complex system composed of interconnected stations that exchange bicycles. They generate digital footprints that reveal the activity in the city over time and space, making possible a quantitative analysis of people's movements. A careful study relying on nonstationary statistical modeling and data mining is done to first model the time evolution of the dynamics of movements with Vélo'v, that is mostly cyclostationary over the week with nonstationary evolutions over larger time-scales, and second to disentangle the spatial patterns to understand and visualize the flows of Vélo'v bicycles in the city. This study gives insights about social behaviors of the users of this intermodal transportation system, the objective being to help in designing and planning policy in urban transportation.

In [14] we investigate diffusion processes in dynamic networks. We propose new notions for measuring the exposure of a node to diffusion processes taking place over the network, that is the likelihood of the node to be affected by such processes. We introduce different exposure scores, based either on contacts or on flows in the dynamic network. We study the distribution of these values in the example case of a real-world dynamic network and investigate possible correlations between them. We also discuss computational complexity issues.

6.3. Community detection: dynamic and overlapping

We conduct two main approach in community detection suitable for dynamic network. The first one is related to overlapping detection and teh second one is to be able to detect dynamic communities.

In [16], we investigate the time evolution as an important feature of communities in network science. It is related with capturing critical events, characterizing community members, and predicting behaviours of communities in networks with time varying. However, most of existing community detection techniques are proposed for static networks. Here, we present a new framework to uncover community structure for each temporal graph over time. In consideration of regularizing time-dependent communities, the high temporal variations will be prevented and the gained results on community evolution become more reasonable. Having applied it on synthetic networks, the experimental results offer new views in dynamic networks

In [13] we focus on overlapping community structure. Overlapping community structure is more reasonable to capture the topology of networks. Despite many efforts to detect overlapping communities, the overlapping community problem is still a great challenge in complex networks. Here we introduce an approach to identify overlapping community structure based on an efficient partition algorithm. In our method, communities are formed by merging peripheral clusters with cores. Therefore, communities are allowed to overlap. We show experimental studies on synthetic networks and real networks to demonstrate that our method has excellent performances in community detection.

7. Contracts and Grants with Industry

7.1. Contracts with Industry

A bilateral contract has been signed between the DNET INRIA and SALOMON to formalize their collaboration in the context of the XtremLog projet. This collaboration is based on an exchange of good services : SALOMON offers to adapt its equipments to integrate the sensor nodes designed by the INRIA for the Marathon des Sables experiment

An extension of this contract is currently under discussion to continue with this collaboration in the SENSBIO work package of the SENSAS ADT.

8. Other Grants and Activities

8.1. Regional Initiatives

8.1.1. ESPAD (FEDER)

Participants: Guillaume Chelius, Sandrine Avakian, Guillaume Roche.

The ESPAD (Embedded Sport Performance Analysis Data) is bio-mechanics / physiology logging project funded by FEDER. The goal is to contributed to the design of a distributed multi-sensor architecture that can be worn by an individual and that records bio-mechanical, physiological and environmental data.

8.1.2. Dispop (IXXI)

Participant: Guillaume Chelius [Prime Investigator].

Dispop is a biologging project funded by the Rhône-Alpes Institute of Complex Sciences. Bio-logging consists in equipping animals with tracking and sensing devices such that its mobility, environmental conditions and social interactions can be monitored. This project's goal is more particularly to explore and develop the measure and analysis tools which could help in modeling the dynamic of populations as a response to environmental factors. This project hosts members of the D-NET team and the DEPE – Département Ecologie, Physiologie et Ethologie department of the IPHC – Institut Pluridisciplinaire Hubert Curien (Strasbourg, France).

8.2. National Initiatives

8.2.1. SensLAB (ANR)

Participants: Eric Fleury [Prime Investigator], Guillaume Chelius, Jean-Pierre Poutcheu.

The purpose of the SensLAB project is to deploy a very large scale open wireless sensor network platform. SensLAB's main and most important goal is to offer an accurate and efficient scientific tool to help in the design, development, tuning, and experimentation of real large-scale sensor network applications. The sensLAB platform is distributed among 4 sites and is composed of 1,024 nodes. Each location hosts 256 sensor nodes with specific characteristics in order to offer a wide spectrum of possibilities and heterogeneity. The four test beds are however part of a common global testbed as several nodes will have global connectivity such that it will be possible to experiment a given application on all 1K sensors at the same time.

8.2.2. FLab (ANR)

Participant: Eric Fleury.

As proposed by initiatives in Europe and worldwide, enabling an open, general-purpose, and sustainable large-scale shared experimental facility will foster the emergence of the Future Internet. There is an increasing demand among researchers and production system architects to federate testbed resources from multiple autonomous organizations into a seamless/ubiquitous resource pool, thereby giving users standard interfaces for accessing the widely distributed and diverse collection of resources they need to conduct their experiments. The F-Lab project builds on a leading prototype for such a facility: the OneLab federation of testbeds. OneLab pioneered the concept of testbed federation, providing a federation model that has been proven through a durable interconnection between its flagship testbed PlanetLab Europe (PLE) and the global PlanetLab infrastructure, mutualising over five hundred sites around the world. One key objective of F-Lab is to further develop an understanding of what it means for autonomous organizations operating heterogeneous testbeds to federate their computation, storage and network resources, including defining terminology, establishing universal design principles, and identifying candidate federation strategies. On the operational side, F-Lab will enhance OneLab with the contribution of the unique sensor network testbeds from SensLAB, and LTE based cellular systems. In doing so, F-Lab continues the expansion of OneLab's capabilities through federation with an established set of heterogeneous testbeds with high international visibility and value for users, developing the federation concept in the process, and playing a major role in the federation of national and international testbeds. F-Lab will also develop tools to conduct end-to-end experiments using the OneLab facility enriched with SensLAB and LTE.

F-Lab is a unique opportunity for the French community to play a stronger role in the design of federation systems, a topic of growing interest; for the SensLAB testbed to reach an international visibility and use; and for pioneering testbeds on LTE technology.

The purpose of the SensLAB project is to deploy a very large scale open wireless sensor network platform. SensLAB's main and most important goal is to offer an accurate and efficient scientific tool to help in the design, development, tuning, and experimentation of real large-scale sensor network applications. The sensLAB platform is distributed among 4 sites and is composed of 1,024 nodes. Each location hosts 256 sensor nodes with specific characteristics in order to offer a wide spectrum of possibilities and heterogeneity. The four test beds are however part of a common global testbed as several nodes will have global connectivity such that it will be possible to experiment a given application on all 1K sensors at the same time.

8.2.3. SensTOOLS (INRIA ADT)

Participants: Eric Fleury [Prime Investigator], Guillaume Chelius.

The main and most important goal of the SensTOOLS ADT project is to foster the design, development, tuning, and experimentation of real large scale sensor network applications. Sensor networks have recently emerged as a premier research topic. However, due to their massively distributed nature, the design, implementation, and evaluation of sensor network applications, middleware, and communication protocols are difficult time-consuming tasks. The purpose of the SensTOOLS is to provide both software and hardware toolboxes in order to offer the developer appropriate tools and methods for designing, testing and managing his/her large scale wireless sensor network applications.

8.2.4. SensAS (INRIA ADT)

Participants: Eric Fleury [Prime Investigator], Guillaume Chelius.

The ambition of SensAS is to deploy wireless sensor and actuator applications. From the strong expertise gather in MOSAR, SensLAb and SensTOOLS, the goal is to transfer and help other INRIA research team to deploy their own application, not in the restricted networking area: flying drones, robots fleet, biologging, health, management.

8.2.5. DyVi (INRIA ARC)

Participants: Eric Fleury [Prime Investigator], Qinna Wang, Adrien Friggeri.

The goal of the ARC DyVi is to build a foundation for dynamic graph theory in order to be able to describe properties and design efficient and specific algorithmic for dynamic graph and overlapping communities The goal is to be able to tackle multi time scale visualization tools based on TULIP, to implement data structure / handling / time scale aggregation / browsing within the TULIP software developed by the INRIA GRAVITE team. We also target epidemic process visualization in order to be able to run and "see" dynamic processes on dynamic networks

8.3. European Initiatives

8.3.1. MOSAR (FP6 - LSH)

Participants: Eric Fleury [Scientific leader], Guillaume Chelius, Adrien Friggeri.

MOSAR is an Integrated Project supported for 5 years by the European Commission under the Life Science Health Priority of the Sixth Framework Program. Infections caused by antimicrobial-resistant bacteria (AMRB) account for an increasing proportion of healthcare-associated infections, particularly in high-risk units such as intensive care units and surgery; patients discharged to rehabilitation units often remain carriers of AMRB, contributing to their dissemination into longer-term care areas and within the community. The overall objective of MOSAR is to gain breakthrough knowledge in the dynamics of transmission of AMRB, and address highly controversial issues by testing strategies to combat the emergence and spread of antimicrobial resistance, focusing on the major and emerging multi-drug antimicrobial resistant microorganisms in hospitals, now spreading into the community. Microbial genomics and human response to carriage of AMRB will be integrated with health sciences research, including interventional controlled studies in diverse hospital settings, mathematical modeling of resistance dynamics, and health economics. Results from MOSAR will inform healthcare workers and decision-makers on strategies for anticipating and mastering antimicrobial resistance.

To achieve these objectives, MOSAR brings together internationally recognized experts in basic laboratory sciences, hospital epidemiology, clinical medicine, behavioral sciences, quantitative analysis and modeling, and health economics. MOSAR brings together 11 institutions recognized for their leadership in these areas, from 10 EU Member or Associated States, as well as 7 SMEs to develop and validate high-throughput automated molecular tools for detection of AMRB.

8.3.2. WASP (FP6-IST)

Participants: Eric Fleury, Andreea Chis.

WASP is an Integrated Project supported for 4 years by the European Commission under the Information Society Technologies of the Sixth Framework Program. An important class of collaborating objects is represented by the myriad of wireless sensors, which will constitute the infrastructure for the ambient intelligence vision. The academic world actively investigates the technology for Wireless Sensor Networks (WSN). Industry is reluctant to use these results coming from academic research. A major cause is the magnitude of the mismatch between research at the application level and the node and network level. The WASP project aims at narrowing this mismatch by covering the whole range from basic hardware, sensors, processor, communication, over the packaging of the nodes, the organization of the nodes, towards the information distribution and a selection of applications. The emphasis in the project lays in the self-organization and the services, which link the application to the sensor network. Research into the nodes themselves is needed because a strong link lies between the required flexibility and the hardware design. Research into the applications is necessary because the properties of the required service will influence the configuration of both sensor network and application for optimum efficiency and functionality. All inherent design decisions cannot be handled in isolation as they depend on the hardware costs involved in making a sensor and the market size for sensors of a given type.

8.4. International Initiatives

8.4.1. STIC AMSUD – Dynamics of Layered Complex Networks

Participants: Eric Fleury, Guillaume Chelius, Qinna Wang, Adrien Friggeri.

D-NET is a member of a STIC AMSUD project between the National Laboratory for Scientific Computing (LNCC) in Brazil, the Faculdad de Ingeniera Universidad de Buenos Aires in Argentina, Laboratoire d'Informatique de Paris 6 (LIP6) and ENS Lyon in France. The goal of the project is mainly to investigate the fundamental characteristics of dynamic graphs and their applicability to the analysis of layered complex networks.

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Leadership within scientific community

- Guillame Chelius was member of the Ph.D. jury of Sadaf Tanvir (Drakkar team, IMAG, France).
- Guillame Chelius was member of the Ph.D. jury of Thomas Claveirole (LIP6, Université Paris 6, France).
- Guillaume Chelius is a member of the IXXI – Complex Systems Institute direction committee.
- Guillaume Chelius is the scientific correspondant of the SENSBIO work package of the SENSAS ADT.
- Eric Fleury was member and reviewer of the Ph.D. jury of Lionel Tabournier (SPEC/CEA Saclay, France).
- Eric Fleury was member of the Ph.D. jury of Romain Kuntz (LSIIT, France).

- Eric Fleury was member of the HDR. jury of Clémence Magnien (LIP6, France).
- Eric Fleury was member of the professor and associate professor selection comity at Grenoble, Bordeaux, ENS de Lyon.
- Eric Fleury is Co-chair of the Networking group ResCom of the CNRS GDR ASR. He also a member of the scientific committee of the GDR ASR.
- Eric Fleury is head of the CNRS National platform on sensor network RECAP.
- Eric Fleury is in the scientific board and in the steering committee of the IXXI – Complex Systems Institute.
- Eric Fleury has been an expert for Swiss National Science Foundation (SNSF), for the Natural Sciences and Engineering Research Council of Canada (NSERC), for the Fond de la Recherche Scientifique of Belgium (FNRS).
- Eric Fleury was on the board of the French ANR VERSO program.
- Eric Fleury is a member of the national PES board for the computer science section.

9.1.2. Editorial boards, conference and workshop committees

- Guillaume Chelius was a member of the ACM PEWASUN 2010 Program Committee.
- Guillaume Chelius was a Guest Editor of the Eurasip JWCN Special Issue on Simulators and Experimental Testbeds Design and Development for Wireless Networks
- Eric Fleury was co chair of the International Workshop on Dynamic Networks (WDN 2010).
- Eric Fleury was a member of the DCOSS program committee.

9.1.3. Invited conferences and other talks

- Guillaume Chelius made various television (TV5 monde, France 5), radio interventions (RFI, France Inter, RMC Sport) related to the XtremLog project and its participation to 25th Sultan the Marathon des Sables.
- Guillaume Chelius was an invited speaker at the the Innosport conference (Voiron, France).
- Guillaume Chelius was an invited speaker at the RGE workshop (Nancy, France).
- Guillaume Chelius was an invited speaker for the AERES review of the INRIA Grenoble Rhône-Alpes Research Unit.
- Guillaume Chelius was an invited speaker at Orange R&D WSNet workshop.
- Guillaume Chelius was an invited speaker at the First Symposium JFFOE in Grenoble, France.
- Guillaume Chelius presented the HIKOB project at the Grenoble Innovation Fair 2010 in Grenoble, France
- Eric Fleury was an invited speaker at the ADREAM conference, LAAS, Toulouse.
- Eric Fleury was an invited speaker at the IRIT Seminar, Toulouse.
- Eric Fleury was an invited speaker at the STIC Amsud / Math AMSUD Workshop, in Buenos Aires, Argentina.
- Eric Fleury was an invited speaker at the fOSSa 2010 (Free/Open Source Software for Academics) conference, Grenoble, France.
- Eric Fleury was an invited speaker at the Workshop on Scientific Computing in Health Applications, LNCC, Brazil.

9.2. Teaching

- Guillaume Chelius has given the *Wireless Networks* class in the Master 2 System and Networks, IFI (Hanoi, Vietnam)
- Guillaume Chelius has partially given the Algorithms for Networks and Communications in the Fundamental Computer Sciences Master at Department of computer science of ENS Lyon (Lyon, France)
- Eric Fleury is a professor at ENS Lyon in the Computer Science Department since 2007. The ENS Lyon is one of the four Ecoles normales supérieures in France. Eric Fleury is in charge of the undergraduate course on "Introduction to Algorithm" and on "Architecture, System and Networking".
- Eric Fleury is in charge for the CS department of the new option in modeling complex systems.
- Since September 2009, Eric Fleury is the Head of the Computer Science Department at ENS Lyon.

10. Bibliography

Major publications by the team in recent years

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[2] A. FRIGGERI, G. CHELIUS, E. FLEURY, A. FRABOULET, F. MENTRÉ, J.-C. LUCET. *Reconstructing Social Interactions Using an unreliable Wireless Sensor Network*, in "Computer Communications", July 2010, vol. 33, n^o 12 [*DOI :* 10.1016/J.COMCOM.2010.06.005], http://hal.inria.fr/inria-00490195/en.

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Articles in International Peer-Reviewed Journal

[5] F. BADER, G. CHELIUS, C. IBARS, M. IBNKAHLA, N. PASSAS, A.-R. RHIEMEIER. *Editorial: Simulators and Experimental Testbeds Design and Development for Wireless Networks*, in "Eurasip Journal on Wireless Communications and Networking", May 2010, vol. 2010 [*DOI :* 10.1155/2010/603970], http://hal.inria.fr/inria-00483766/en.

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[10] E. BEN HAMIDA, G. CHELIUS. *Investigating the Impact of Human Activity on the Performance of Wireless Networks – An Experimental Approach*, in "11th IEEE International Symposium on a "World of Wireless, Mobile and Multimedia Networks" (WoWMoM 2010)", Canada Montreal, IEEE, June 2010, http://hal.inria.fr/inria-00483773/en.

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[14] J. DUMAS, C. CRESPELLE, E. FLEURY. *New Parameters for Measuring Exposure to Diffusion in Dynamic Networks*, in "LAWDN - Latin-American Workshop on Dynamic Networks", Argentina Buenos Aires, INTECIN - Facultad de IngenierÌa (U.B.A.) - I.T.B.A., 2010, 4 p., http://hal.inria.fr/inria-00531748/en.

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