



Activity Report 2015

## **Project-Team FUN**

self-organizing Future Ubiquitous Network

RESEARCH CENTER  
Lille - Nord Europe

THEME  
Networks and Telecommunications



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## Project-Team FUN

*Creation of the Team: 2012 January 01, updated into Project-Team: 2013 July 01*

### Keywords:

#### **Computer Science and Digital Science:**

- 1.2.1. - Dynamic reconfiguration
- 1.2.3. - Routing
- 1.2.4. - QoS, performance evaluation
- 1.2.5. - Internet of things
- 1.2.6. - Sensor networks
- 1.2.7. - Cyber-physical systems
- 1.4. - Ubiquitous Systems

#### **Other Research Topics and Application Domains:**

- 6.4. - Internet of things
- 7. - Transport and logistics
- 8. - Smart Cities and Territories

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## 2. Overall Objectives

### 2.1. Overall Objectives

#### Context.

The Internet of Things [35] is a large concept with multiple definitions. However, the main concepts are the same in every vision and could be summed up as follows: *Imagine a world where every object has the capacity to communicate with its environment. Everything can be both analogue and digitally approached - reformulates our relationship with objects - things - as well as the objects themselves. Any object relates not only to you, but also to other objects, relations or values in a database. In this world, you are no longer alone, anywhere.* (Internet of Things council).

Future Ubiquitous Networks (FUN) are part of the Internet of Things. They are composed of tens to thousands heterogeneous hardware-constrained devices that interact with our environment and the physical world. These devices have limited resources in terms of storage and computing capacities and energy. They communicate through unreliable and unpredictable short-range wireless links and run on batteries that are not envisaged to be changed in current systems since generally deployed in hostile environments. Providing FUNs with energy saving protocols is thus a key issue. Due to these specific features, any centralized control is not conceivable, the new generation of FUNs must be autonomous, be self-organized and dynamically adapt to their environment. The devices that compose CPNs can be sensors, small robots, RFID readers or tags.

Objects or things can now communicate with their environment through the use for instance of an RFID (Radio Frequency IDentification) tag that provides them a unique identifier (ID) and a way to communicate through radio waves.

In the case of a simple passive **RFID tag**, the thing only embeds a tag equipped with an antenna and some memory. To communicate, it needs to be powered by the electromagnetic field of an RFID reader. This reader may then broadcast the information read on tag over a network.

When this tag is equipped with a battery, it is now able to communicate with nearby things similar to itself that may relay its message. Tags can also be equipped with additional capacity and sensors (for light, temperature, etc...). The Internet of Things can thus now refer to a **wireless sensor** network in which each sensor sends the data it collects over its environment and then sends it to a sink, *i.e.* a special sensor node able to analyze those data. In every case, RFID tags or sensor nodes can **be moved unexpectedly** like hold by moving things or animals. We speak then about '**undergone mobility**'.

So far, things can thus communicate information about their environment. But when the capacity of sensors is extended even further, they can also act on their environment (for instance, the detection of an event (fire) may trigger an action like switching the light or fire hoses on). Sensor nodes become **actuators**. When this extended capacity is the faculty to move, actuators are also referred as actors or robots. In this latter case, the mobility is computed on purpose, we then speak about '**controlled mobility**'. Actuators are not moved but move by themselves.

The FUN research group aims to focus on self-organizing techniques for these heterogeneous Future Ubiquitous Networks (FUNs). FUNs need various self-organization techniques to work properly. Self-organization encompasses neighbor discovery (which what other devices a sensor/actuator can communicate directly?), communication, self-deployment, self-localization, activity scheduling (when to wake up, when to send data to save energy without being detrimental to the well behavior of the network, etc)...

Solutions provided by FUN should facilitate the use of FUNs and rub away heterogeneity and difficulties. These techniques should be **scalable, energy-aware, standard-compliant**, should manage undergone **mobility** and take advantage of controlled mobility when available [43].

Solutions provided by FUN will consider vagaries of the realistic wireless environment by integrating cross-layer techniques in their design.

#### **Motivation.**

To date, many self-organizing techniques for wireless sensor networks and mobile ad hoc networks arise in the literature and also from the POPS research group. Some of them are very efficient for routing [36], [34], discovering neighborhood [41], [40], scheduling activity and coverage [38], localizing [44], [33], etc. Nevertheless, to the best of our knowledge, most of them **have not been validated by experimentation**, only by simulation and thus cannot consider the real impact of the wireless links and real **node mobility** in different environments. In addition, some of them rely on assumptions that are known not to be true in realistic networks such as the fact that the transmission range of a node is a perfect disk. Other may perform well only when nodes are static. None of them considers to **take advantage of controlled mobility** to enhance performances. Similarly, many propositions arise regarding self-organization in RFID networks, mainly at the middleware level [45], [37] and at the MAC layer level [31]. Although these latter propositions are generally experimented, they are validated only in static environments with very few tags and readers. To fit realistic features, such algorithms should also be evaluated with regards to scalability and mobility.

RFID and sensor/actor technologies **have not been merged**. Though, RFID readers may now be mobile and communicate in a wireless peer-to-peer manner either with other RFID readers or wireless sensor nodes and all belong to the same network. This implies a study of the standards to allow inter-dependencies in a transparent manner. Although such works have been initiated inside EPC Global working groups, research actions remain scarce.

FUN research group aims at **filling this scientific gap** by proposing self-stabilizing solutions, considering vagaries of wireless links, node mobility and heterogeneity of nodes in compliance with current standards. Validation by experimentation is mandatory to prove the effectiveness of proposed techniques in realistic environments.

FUN will investigate new protocols and communication paradigms that allow the **transparent merging** of technologies. Objects and events might interconnect while **respecting on-going standards** and building an autonomic and smart network while being compliant with hardware resources and environment. FUN expects to rub away the difficulty of use and programmability of such networks by unifying the different technologies. In addition, FUN does not only expect to validate the proposed solutions through experimentation but also to learn from these experiments and from the observation of the impact of the wireless environment to take these features into consideration in the design of future solutions.

## **3. Research Program**

### **3.1. Introduction**

The research area of FUN research group is represented in Figure 1. FUN research group will address every item of Figure 1 starting from the highest level of the figure, *i.e.* in area of homogeneous FUNs to the lowest one. Going down brings more applications and more issues to solve. Results achieved in the upper levels can be re-used in the lower ones. Current networks encountered nowadays are the ones at the higher level, without any interaction between them. In addition, solutions provided for such networks are rarely directly applicable in realistic networks because of the impact of the wireless medium.

FUN research group intends to fill the scientific gap and extend research performed in the area of wireless sensor and actor networks and RFID systems in two directions that are complementary and should be performed in parallel:

- **From theory to experimentation and reciprocally** On one hand, FUN research group intends to investigate new self-organization techniques for these future networks that take into account realistic parameters, emphasizing experimentation and considering mobility.
- **Towards heterogeneous FUNs** On the other hand, FUN research group intends to investigate techniques to allow heterogeneous FUNs to work together in a transparent way for the user. Indeed, new applications integrating several of these components are very much in demand (i.e. smart building) and thus these different technologies need to cooperate.

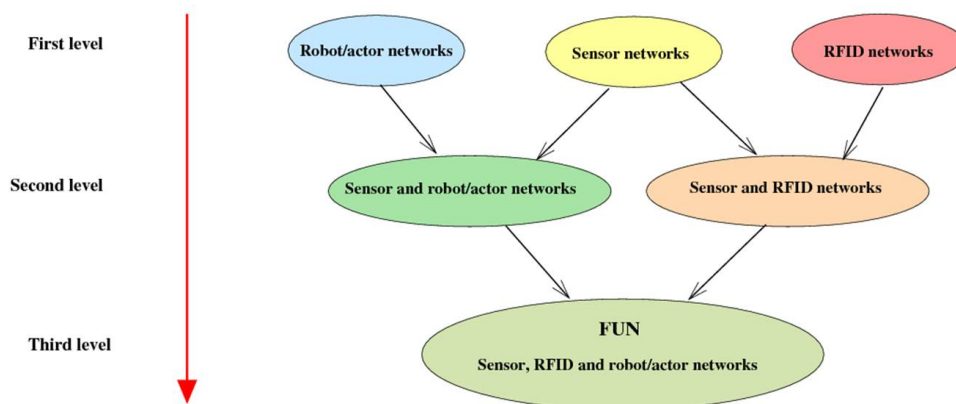


Figure 1. Panorama of FUN.

### 3.2. From theory to experimentation and reciprocally

Nowadays, even if some powerful and efficient propositions arise in the literature for each of these networks, very few are validated by experimentations. And even when this is the case, no lesson is learnt from it to improve the algorithms. FUN research group needs to study the limits of current assumptions in realistic and mobile environments.

Solutions provided by the FUN research group will mainly be algorithmic. These solutions will first be studied theoretically, principally by using stochastic geometry (like in [40]) or self-stabilization [42] tools in order to derive algorithm behavior in ideal environment. Theory is not an end in itself but only a tool to help in the characterization of the solution in the ideal world. For instance, stochastic geometry will allow quantifying changes in neighborhood or number of hops in a routing path. Self-stabilization will allow measuring stabilization times.

Those same solutions will then be confronted to realistic environments and their 'real' behavior will be analyzed and compared to the expected ones. Comparing theory, simulation and experimentation will allow the influence of a realistic environment be better measured. From this and from the analysis of the information really available for nodes, FUN research group will investigate some means either to counterbalance these effects or to take advantage of them. New solutions provided by the FUN research group will take into consideration the vagaries of a realistic wireless environment and the node mobility. New



protocols will take as inputs environmental data (as signal strength or node velocity/position, etc) and node characteristics (the node may have the ability to move in a controlled way) when available. FUN research group will thus adopt a **cross-layered** approach between hardware, physical environment, application requirements, self-organizing and routing techniques. For instance, FUN research group will study how the controlled node mobility can be exploited to enhance the network performance at lowest cost.

Solutions will follow the building process presented by Figure 2. Propositions will be analyzed not only theoretically and by simulation but also by experimentation to observe the impact of the realistic medium on the behavior of the algorithms. These observations should lead to the derivation of cross-layered models. Experimentation feedbacks will be re-injected in solution design in order to propose algorithms that best fit the environment, and so on till getting satisfactory behavior in both small and large scale environments. All this should be done in such a way that the resulting propositions fit the hardware characteristics (low memory, CPU and energy capacity) and easy to deploy to allow their use by non experts. Since solutions should take into account application requirements as well as hardware characteristics and environment, solutions should be generic enough and then able to self-configure to adapt their environment settings.

In order to achieve this experimental environments, the FUN research group will maintain its strong activity on platform deployment such as SensLAB [47], FIT [46] and Aspire [32]. Next steps will be to experiment not only on testbeds but also on real use cases. These latter will be given through different collaborations.

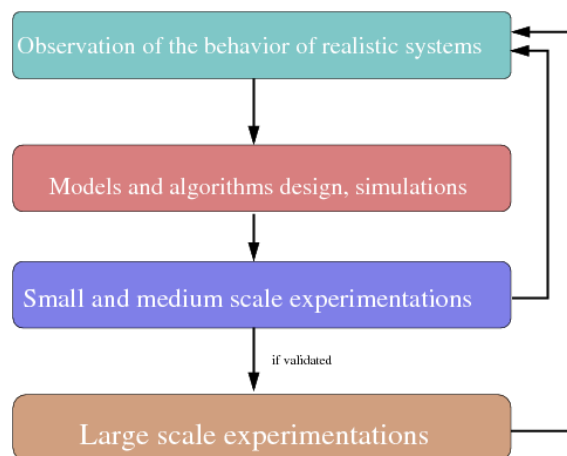


Figure 2. Methodology applied in the FUN research group.

**FUN research group will investigate self-organizing techniques for FUNs by providing cross-layered solutions that integrate in their design the adaptability to the realistic environment features. Every solution will be validated with regards to specific application requirements and in realistic environments.**

**Facing the medium instability.** The behavior of wireless propagation is very depending of the surrounding environment (in-door vs outdoor, night vs day, etc) and is very instable. Many experiments in different environment settings should be conducted. Experiment platforms such as SensLAB, FIT, our wifiBot as robots and actuators and our RFID devices will be used offering ways to experiment easily and quickly in different environments but might not be sufficient to experiment every environment.

**Adaptability and flexibility.** Since from one application to another one, requirements and environments are different, solutions provided by FUN research group should be **generic** enough and **self-adapt** to their environment. Algorithm design and validation should also take into account the targeted applications brought for instance by our industrial partners like Etineo. All solution designs should keep in mind the devices

constrained capacities. Solutions should consume low resources in terms of memory, processor and energy to provide better performances and scale. All should be self-adaptive.

FUN research group will try to take advantage of some observed features that could first be seen as drawbacks. For instance, the broadcast nature of wireless networks is first an inconvenient since the use of a link between two nodes inhibits every other communication in the same transmission area. But algorithms should exploit that feature to derive new behaviors and a node blocked by another transmission should overhear it to get more information and maybe to limit the overall information to store in the network or overhead communication.

### 3.3. Towards unified heterogeneous FUNs

The second main direction to be followed by the FUN research group is to merge networks from the upper layer in Fig. 1 into networks from the lowest level. Indeed, nowadays, these networks are still considered as separated issues. But considering mixed networks bring new opportunities. Indeed, robots can deploy, replace, compensate sensor nodes. They also can collect periodically their data, which avoids some long and multi-hop communications between sensor nodes and thus preserving their resources. Robots can also perform many additional tasks to enhance network performance like positioning themselves on strategic points to ensure area coverage or reduce routing path lengths. Similarly, coupling sensors and RFID tags also bring new opportunities that are more and more in-demand from the industrial side. Indeed, an RFID reader may be a sensor in a wireless sensor network and data hold by RFID tags and collected by readers might need to be reported to a sink. This will allow new applications and possibilities such as the localization of a tagged object in an environment be covered by sensors.

When at last all components are gathered, this leads us to a new era in which every object is autonomous. Let's consider for instance a smart home equipped with sensors and RFID reader. An event triggered by a sensor (*i.e.* an increase of the temperature) or a RFID reader (*i.e.* detection of a tag hold by a person) will trigger actions from actuators (*i.e.* lowering of stores, door opening). Possibilities are huge. But with all these new opportunities come new technological issues with other constraints. Every entity is considered as an object possibly mobile which should be dynamically identified and controlled. To support this dynamics, protocols should be localized and distributed. Model derived from experiment observations should be unified to fit all these classes of devices.

**FUN research group will investigate new protocols and communication paradigms that allow the technologies to be transparently merged. Objects and events might interconnect while respecting on-going standards and building an autonomic and smart network while being compliant with hardware resources and environment.**

Technologies such as wireless sensors, wireless robots/actuators and RFID tags/ readers, although presenting many common points are still part of different disciplines that have evolved in parallel ways. Every branch is at different maturity levels and has developed its own standards. Nevertheless, making all these devices part of a single unified network leverages technological issues (partly addressed in the former objective) but also regarding to on-going standards and data formatting. FUN research group will have to study current standards of every area in order to propose compliant solutions. Such works have been initiated in the POPS research group in the framework of the FP7 ASPIRE project. Members of FUN research group intend to continue and enlarge these works.

Today's EPCGlobal compliant RFID readers must comply to some rules and be configurable through an ALE (Application Level Event) [39]. While a fixed and connected RFID reader is easily configurable, configuring remotely a mobile RFID reader might be very difficult since it implies to first locate it and then send configuration data through a wireless dynamic network. FUN research group will investigate some tools that make the configuration easy and transparent for the user. This remote configuration of mobile readers through the network should consider application requirements and network and reader characteristics to choose the best trade-off relative to the software part embedded in the reader. The biggest part embedded, the lowest bandwidth overhead (data can be filtered and aggregated in the reader) and the greater mobility (readers are still fully operational even when disconnected) but the more difficult to set up and the more powerful readers. All these aspects will be studied within the FUN research group.

## 4. Application Domains

### 4.1. Application Domains

The set of applications enabled through FUN and IoT is very large and can apply in every application area. We can thus not be exhaustive but among the most spread applications, we can name every area, event or animal monitoring, understanding and protection. To illustrate this, we may refer to the use cases addressed by our PREDNET project which goals is to equip rhinoceros with smart communicating devices to fight against poaching.

Other field of application is exploration of hostile and/or unknown environment by a fleet of self-organizing robots that cooperate with RFID and sensors to ensure a continue monitoring afterwards.

Also, IoT and FUN can play a key role in logistics and traceability by relying on the use of sensors or RFID technologies as implemented in our TRACAVERRRE project or our collaboration with the start up TRAXENS.

Finally, IoT and FUN leverage a lot of applications in Smart City concept , ranging from parking aid to a better energy consumption going through air quality monitoring, traffic fluidizing etc. (See our CityLab Inria and VITAL projects).

## 5. Highlights of the Year

### 5.1. Highlights of the Year

- Inauguration of the FIT IoT Lab Lille's platform with its first robots open to the community.
- Full description of the TraxNet communication stack in the framework of our collaboration with TRAXENS, with real in situ experiments on the container ships Bougainville and America Vespucci. (3 pending patents)
- The FIT facility has been proposed as an "Infrastructure de Recherche" (Infrastructure for Research) by the CD TGIR.

#### 5.1.1. Awards

The TRACAVERRRE project has been nominated for the Prix de l'Innovation VINCI 2015.

## 6. New Software and Platforms

### 6.1. IoT-LAB robots

KEYWORDS: Internet of things - Robotics

FUNCTIONAL DESCRIPTION

IoT-LAB robots is an embedded robot controller on a Turtlebot2 providing the IoT-LAB node mobility functionality.

- Partner: Université de Strasbourg

### 6.2. FIT IoT-Lab

**Participants:** Raymond Borenstein, Nathalie Mitton [correspondant], Julien Vandaele.

FIT IoT-LAB is a very large scale open testbed that features over 2700 wireless sensor nodes and more than 200 robots spread across six different sites in France. Nodes are either fixed or mobile and can be allocated in various topologies throughout all sites. A variety of wireless sensors are available, with different processor architectures (MSP430, STM32 and Cortex-A8) and different wireless chips (802.15.4 PHY at 800 MHz or 2.4 GHz). In addition, "open nodes" can receive custom wireless sensors for inclusion in IoT-LAB testbed. This platform is completely open and can be used by any one wishing to run experiment on wireless sensors and robots.

The Lille site displays 3 subsets of the platforms:

- Euratechnologies : this site features 256 WSN430 sensor nodes operating in the 2.4GHz band. 64 nodes are mobile, embedded on mobile trains.
- Haute Borne : this site features 256 M3 sensor nodes operating in the 2.4GHz band and 64 mobile robots (32 turtlebots and 32 wifibots) completely remotely programmable.
- Opennodes : this site will feature (opening beginning 2015) 64 hardware open slots to allow any one to plug his own hardware and benefits from the platform debugging and monitoring tools.

## 7. New Results

### 7.1. Data gathering and coverage in WSN

**Participants:** Nathalie Mitton, Tahiry Razafindralambo, Arunabha Sen.

Data availability is one of the main goals and challenges in Future Ubiquitous Network and especially in Wireless Sensor Networks. Indeed, gathering and collecting data in a mobile environment is a very challenging task. In [12], the authors use data mules to organize the data collection from the sensor in the field. The results presented in [12] are based on some new and unique assumptions. First, it is assumed that the mules are mobile but also the sensors that generate the data to be collected. Second, we collection time is not the first optimization criteria. The focus of the paper is on minimizing the number of mules given a time constraints. The problem is shown to be NP complete and a transformation of the problem into a minimum flow problem allow the computation of optimal solution using Integer Linear Programming.

The results presented in [5] use the assumption of a mobile objects tracked by some other mobile objects as in [12]. In the case of [5] the focus is on coverage of mobile targets by mobile Unmanned Aerial Vehicle. The paper takes two major assumptions regarding the limited energy of UAV and the observation range. These two constraints are linked with each other since when the UAV increase its altitude, it consumes more energy but also increase its observation range. The problem under consideration is mathematically represented by defining mixed integer non-linear optimization models. Heuristic procedures are defined and they are based on restricted mixed integer programming (MIP) formulation of the problem. A computational study is carried out to assess the behavior of the proposed models and MIP-based heuristics.

### 7.2. Routing in FUN

**Participants:** Nathalie Mitton, Mouna Rekik.

Geographic routing is an attractive routing strategy in wireless sensor networks. It works well in dense networks, but it may suffer from the void problem. For this purpose, a recovery step is required to guarantee packet delivery. Face routing has widely been used as a recovery strategy since proved to guarantee delivery. However, it relies on a planar graph not always achievable in realistic wireless networks and may generate long paths. In [25], we propose GRACO, a new geographic routing algorithm that combines a greedy forwarding and a recovery strategy based on swarm intelligence. During recovery, ant packets search for alternative paths and drop pheromone trails to guide next packets within the network. GRACO avoids holes and produces near optimal paths. Simulation results demonstrate that GRACO leads to a significant improvement of routing performance and scalability when compared to the literature algorithms.

GRACO has first been designed in the general case. We then studied its applicability to the Virtual Power Plants and their specific data packets with different priorities [22], [24]. Indeed, the Smart Grid (SG) incorporates communication networks to the conventional electricity system in order to intelligently integrate distributed energy resources (DERs) and allow for demand side management. The move to Smart grid in developing countries has to cope with great disparities of ICT infrastructures even within the same city. Besides, individual DERs are often too small to be allowed access to energy market, likewise power utilities are unable to effectively control and manage small DERs. We propose the use of affordable and scalable wireless communication technology to aggregate geographically sparse DERs into a single virtual power plant. The enrollment of prosumers in the VPP is conditional to financial performance of the plant. Thus, the VPPs are dynamic and are expected to scale up as more and more prosumers are attracted by their financial benefits. the communication network has to follow this progression and therefore to be scalable and rapidly deploy-able. We present a routing algorithm for data communication within the VPP to support centralized, decentralized or fully distributed control of the VPP's DERs.

Based on this study, we adapted GRACO so it can fit the specific cases of Smart Grid [23] and more specifically to the Neighbor Area Networks (NAN) of Smart Grids, or distribution segment of the power system in the smart grid (SG). The deployment of ICT to support conventional grid will solve legacy problems that used to prevent implementation of smart services such as smart metering, demand side management or the integration of Distributed Energy Resources (DERs) within the smart grid. We demonstrate the effectiveness of GRACO in terms of scalability, peer-to-peer routing, end-to-end delay and delivery rate.

### 7.3. Deployment and Self-Deployment in FUN

**Participants:** Nathalie Mitton, Valeria Loscri, Tahiry Razafindralambo.

Mobility management is a difficult task in autonomous networks. However, mobility provide a huge advantage when in comes to specific scenario such as emergency-related ones especially when network connection must be restored to provide basic network access to users. [3] investigates the potential of spontaneous networks for providing Internet connectivity over the emergency area through the sharing of resources owned by the end-user devices. Novel and extremely flexible network deployment strategies are required in order to cope with the user mobility, the limited communication capabilities of wireless devices, and the intrinsic dynamics of traffic loads and QoS requirements. In [3], a novel architecture is proposed to take advantage of existing end-user devices and some algorithm, are described to build and efficiently exploit the spontaneous emergency network.

Following the emergency scenario described in [3], [15] and [21] describe an algorithm to minimizes the control traffic generated by specific nodes in the network used repair the network and the deployment of these specific nodes. This nodes, forming a substitution network, in case of emergency, are injected autonomously in the network by the network to restore basic network service. In order to increase the performance of the network, the injected nodes called substitution routers, use their ability to move to change the shape of the network and to increase its performance. These movements needs huge amount of control messages to maintain consistency regarding routers' positions. [15] and [21] give an algorithm for the deployment of these routers and the autoregressive time serie model to reduce the amount of control traffic used for the deployment.

### 7.4. Smart Cities

**Participants:** Nathalie Mitton, Valeria Loscri, Riccardo Petrolo.

Smart City represents one of the most promising, prominent and challenging Internet of Things (IoT) applications, but recent ICT trends suggest more and more that cities could also benefit from Cloud computing. The convergence of IoT paradigm and Cloud computing technology, can play a fundamental role for developing of highly level and organized cities form an ICT point of view, but it is of paramount importance to deal a critical analysis to identify the issues and challenges deriving from this synergy. This detailed study has been dealt in [7], where it is shown as the semantic annotation of the sensors in the cloud, and innovative services can be implemented and considered by bridging Cloud and Internet of Things. The Cloud of Things

(CoT) paradigm is also considered in [16], where it is shown how the CoT arrives to better distribute resources, putting together and enabling therefore a horizontal integration of various Internet of Things(IoT) platforms. Semantic interoperability of diverse IoT platforms are also a key concept in [18], where the virtualization of different IoT systems in order to model and represent the architecture in accordance with the common standards-based IoT ontologies is applied. The environment comes with a range of visual drag-and-drop tools, which boosts developers' productivity.

## 7.5. RFID

**Participant:** Nathalie Mitton.

One of the devices under consideration by the FUN team is RFID. One of the main issues to widely deploy RFID reader is reader-to-reader collision. Indeed, when the electromagnetic fields of the readers overlap, a collision occurs on the tag laying in the overlapping section and cannot be read. In [10], we propose a high adaptive contention-based medium access control (HAMAC) protocol that considerably reduces readers collision problems in a large-scale dynamic RFID system. HAMAC is based only on realistic assumptions that can be experimented and does not require any additional components on RFID reader in order to improve the performance in terms of throughput, fairness and latency. The central idea of the HAMAC is for the RFID reader to use a WSN-like CSMA approach and to set its initial backoff counter to the maximum value that allows to mitigate collision. Then, according to the network congestion on physical channels the reader tries to dynamically control its contention window by linear decreasing on selected physical channel or multiplicative decreasing after scanning all available physical channels. Extensive simulations are proposed to highlight the performance of HAMAC compared to literature's work in large-scale RFID systems where both readers and tags are mobile. Simulation results show the effectiveness and robustness of the proposed anti-collision protocol in terms of network throughput, fairness, coverage and time to read all tags.

## 7.6. Localization

**Participants:** Nathalie Mitton, Roudy Dagher, Valeria Loscri, Salvatore Guzzo Bonifacio.

[20] presents our approach to localize a node with the use of only one landmark. It is a passive and non intrusive cross-layer approach that relies on a signal processing of all received signals. Results are evaluated by simulation and show good accuracy. To complete the previous study, we developed [11] a novel array-based method to estimate the path loss exponent (PLE). The method is designed as a part of an automatic calibration step, prior to localization of a source transmitting in the near-far field of the array. The method only requires the knowledge of the ranges between the array elements. By making the antenna elements transmit in turn, the array response model in the near-far field is exploited to estimate the current environment PLE. Simulation results show that this method can achieve good performance with one transmission round. The performance of the PLE estimation is investigated in the context of source localization with a sensitivity analysis to the PLE estimation. These works are the purpose of a pending patent (submitted in March 2015).

Alternatively, we derive similar localization schemes to enable a cooperation between mobile robots to locate a target based on RSSI [13]. Received Signal Strength Indicator (RSSI) is commonly considered and is very popular for target localization applications, since it does not require extra-circuitry and is always available on current devices. Unfortunately, target localizations based on RSSI are affected with many issues, above all in indoor environments. In this paper, we focus on the pervasive localization of target objects in an unknown environment. In order to accomplish the localization task, we implement an Associative Search Network (ASN) on the robots and we deploy a real test-bed to evaluate the effectiveness of the ASN for target localization. The ASN is based on the computation of weights, to "dictate" the correct direction of movement, closer to the target. Results show that RSSI through an ASN is effective to localize a target, since there is an implicit mechanism of correction, deriving from the learning approach implemented in the ASN.

## 7.7. Vehicular Networks

**Participants:** Nathalie Mitton, Valeria Loscri.



In the framework of our collaboration with Southern University in China, we investigate a specific issue in Vehicular AdHoc Networks (VANET), the information delivery delay analysis for roadside unit deployment in a VANET with intermittent connectivity [9]. A mathematical model is developed to describe the relationship between the average delay for delivering road condition information and the distance between two neighbor RSUs deployed along a road. The derived mathematical model considers a straight highway scenario where two RSUs are deployed at a distance without any direct connection and vehicles are sparsely distributed on the road with road condition information randomly generated between the two neighbor RSUs. Moreover, the model takes into account the vehicle speed, the vehicle density, the likelihood of an incident, and the distance between two RSUs. The effectiveness of the derived mathematical model is verified through simulation results. Given the information delivery delay constraint of a time-critical application, this model can be used to estimate the maximum distance allowed between two neighbor RSUs, which can provide a reference for the deployment of RSUs in such scenarios.

But Vehicular Networks can also convey social networks. In [30], we survey recent literature on Vehicular Social Networks that are a particular class of vehicular ad hoc networks, characterized by social aspects and features. Starting from this pillar, we investigate perspectives of next generation vehicles under the assumption of social networking for vehicular applications (i.e., safety and entertainment applications). This paper plays a role as a starting point about socially-inspired vehicles, and main related applications, as well as communication techniques. Vehicular communications can be considered as the "first social network for automobiles", since each driver can share data with other neighbors. As an instance, heavy traffic is a common occurrence in some areas on the roads (e.g., at intersections, taxi loading/unloading areas, and so on); as a consequence, roads become a popular social place for vehicles to connect to each other. Human factors are then involved in vehicular ad hoc networks, not only due to the safety related applications, but also for entertainment purpose. Social characteristics and human behavior largely impact on vehicular ad hoc networks, and this arises to the vehicular social networks, which are formed when vehicles (individuals) "socialize" and share common interests. This survey describes the main features of vehicular social networks, from novel emerging technologies to social aspects used for mobile applications, as well as main issues and challenges. Vehicular social networks are described as decentralized opportunistic communication networks formed among vehicles. They exploit mobility aspects, and basics of traditional social networks, in order to create novel approaches of message exchange through the detection of dynamic social structures. An overview of the main state-of-the-art on safety and entertainment applications relying on social networking solutions is also provided.

## 7.8. FIT

**Participants:** Nathalie Mitton, Julien Vandaele.

The universal proliferation of intelligent objects is making Internet of Things (IoT) a reality; to operate on a large scale it will critically rely on new, seamless, forms of communications. But how can innovations be validated in a controlled environment, before being massively deployed into the real world? Several platforms have been deployed to address this issue. In [8], we browse a survey of them, highlighting their characteristics and given some tips to choose the most appropriate to our needs.

Our team has contributed to the deployment of the FIT IoT-LAB platform [2], [19], [27], which addresses this challenge by offering a unique open first class service to all IoT developers, researchers, integrators and developers: a large-scale experimental testbed allowing design, development, deployment and testing of innovative IoT applications, in order to test the future and make it safe. One of the specific deployment focuses on the automatic docking of robots for energy recharge. We explain it in [17]. The objective is to achieve long-term autonomous robots within an experiment test-bed. We propose to combine the use of QR codes as landmarks and Infrared distance sensors. The relative size of the lateral edges of the visual pattern is used to position the robot in relation with the dock. Infrared distance sensors are then used to perform different approaching strategies depending on the distance. Experiments show that the proposed solution is fully operational and robust. Not to rely exclusively on visual pattern recognition avoids potential errors induced by camera calibration. Additionally, as a positive side effect, the use of Infrared sensors allows the robot to avoid obstacles while docking. The finality of such an approach is to integrate these robots into the

FIT IoT Lab experimental testbed which allows any experimenter to book wireless resources such as wireless sensors remotely and to test their own code. Wifibots holding wireless sensors will be integrated as additional reservable resources of the platform to enlarge the set of possible experimentations with mobile entities.

## 7.9. New and other communication paradigms

**Participants:** Nathalie Mitton, Valeria Loscri, Arash Maskooki, Gabriele Sabatino.

Interconnection and self-organized systems are normally populated with heterogeneous and different devices. The differences range from computational capabilities, storage size, etc. Instead of considering the heterogeneity as a limitation, it is possible to "turn it" as a primitive control of the system, in order to realize more robust and more resilient communication systems. Based on these premises, we identify specific situations, where mobile nodes with a plethora of interesting features and sensing capacities, can be exploited by configuring them in such a way to make them playing different roles in respect of them for which they have been initially conceived [4]. The differentiated use of devices, together with a careful analysis of the characteristics and performance requirements of the current and the future networks, allow the adaptation to the exponential growth in demand for high bandwidth applications [26]. This is exactly the philosophy embraced in [28], where Software Defined Radio (SDR) and Cognitive Radio (CR) have been considered and analyzed in a novel context, namely body networked systems. A detailed analysis of body systems as networked systems has also been considered in [6] and [14]. In [6] a novel communication paradigm, namely a molecular communication, has been considered to show how a nanoparticulate system can be suitable to coexist in a biological environment. An experimental analysis to assess the theoretical assumption has been developed in [14]. In order to assess new/alternative communication paradigms, there is the necessity from one side to consider and analyze the specific context and its level of interaction with the communication system and on the other side the correct identification of the specific features of the communication paradigm itself. This type of analysis allowed the design and implementation of an acoustic communication approach [29], where the ultrasound represent the wave carriers of data information. This "unusual" transmission means has been selected as the most suitable in a context as the body, where the aqueous environment makes it not suitable for more "traditional" communication paradigms, e.g. the one based on Radio Frequency (RF) waves.

## 8. Bilateral Contracts and Grants with Industry

### 8.1. Bilateral Contracts with Industry

- Traxens partnership

**Participants:** Natale Guzzo, Nathalie Mitton [correspondant].

This collaboration aims to set up a full protocol stack for TRAXENS's guideline. This collaboration is a CIFRE contract. In the framework of this collaboration, a full protocol stack has been developed for the purpose of container monitoring. 3 national and 2 international patents have been submitted so far. 2 are under preparation.

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

#### 9.1.1. Tracaverre

**Participants:** Nathalie Mitton [correspondant], Gabriele Sabatino.

Title: Tracaverre

Type: FUI

Duration: November 2012 - Avril 2015

Coordinator: Saver Glass

Others partners: Inria FUN IEMN Courbon Camus La Grande Marque LIRIS DISP

Tracaverre studies the use of RFID for traceability of prestigious bottles. Tracaverre has yielded to the implementation of the T-Scan software.



### 9.1.2. PIPA

**Participant:** Nathalie Mitton [correspondant].

Title: Partager de l'Info PARTout à bas coût

Type: Chercheur citoyen

Duration: Dec 2015 - Dec 2017

Coordinator: Inria FUN

Others partners: SpotTrotter

PIPA project aims to provide an innovative low cost solution to share information in places where communication infrastructure are lacking, insufficient or not adapted, going beyond technical, economical or political limitations.

## 9.2. National Initiatives

### 9.2.1. Inria Project Lab

#### 9.2.1.1. CityLab@Inria

**Participants:** Valeria Loscri, Aziz Mbacke, Nathalie Mitton [correspondant].

Title: CityLab@Inria

Type: IPL

Duration: 2015 - 2019

Coordinator: Valerie Issarny

CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. Obviously, running urban-scale experiments is a central concern of the Lab, so that we are able to confront proposed approaches to actual settings. The Lab's research leverages relevant effort within Inria project-teams that is further revisited as well as integrated to meet the challenges of smart cities. Research themes span: energy-efficient wireless communication protocols, urban-scale social and physical sensing, privacy by design, cloud-based urban data management, data assimilation, visual analysis, and urban system software engineering.

In addition, CityLab Inria research builds upon collaborative effort at the International level, and especially collaboration in the context of the Inria SiliconValley program.

This project has yield to the set up of a full course on Smart Cities via a MOOC.

### 9.2.2. ADT

#### 9.2.2.1. RFunID

**Participants:** Clement Fumey, Nathalie Mitton [correspondant], Julien Vandaele.

Duration: September 2015 - August 2017

Coordinator: Inria FUN

The purpose of this project is to deploy a large scale experimental RFID platform that enables remote programming of RFID scenario on heterogeneous devices.

### 9.2.2.2. ARUNTA

**Participants:** Emilio Compagnone, Valeria Loscri [correspondant], Julien Vandaele.

Title: Arduino-based Robots for Ubiquitous Network (ARUNTA)

Type: ADT

Duration: September 2014 - August 2016

Coordinator: Inria FUN

Abstract: This ADT focuses on the use of Arduino, an open-source electronics prototyping platform, really flexible and easy-to-use [1] to allow a fleet of robots to perform specific tasks. The goal of the ADT is to make experiments on Arduino-based robotic platforms, by implementing two robot cooperation algorithms that have been already tested through simulation tools. In order to extend the users' community and to allow more people to benefit from this research on robot cooperation, this ADT will output a tutorial and a test-bed will be developed. Moreover, the final project will be shared with the Arduino community and every interested user.

### 9.2.3. Equipements d'Excellence

#### 9.2.3.1. FIT

**Participants:** Raymond Borenstein, Nathalie Mitton [correspondant], Julien Vandaele.

Title: Future Internet of Things

Type: EquipEx

Duration: March 2010 - December 2019

Coordinator: UPMC

See also: <http://fit-equipex.fr/>

Abstract: FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It will provide this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project will give French Internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the Future Internet.

FIT is one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Equipements d'Excellence" (Equipex) research grant program. Coordinated by Professor Serge Fdida of UPMC Sorbonne Universités and running over a nine-year period, the project will benefit from a 5.8 million euro grant from the French government.

This project has yield to several publications in 2015: [2], [8], [17], [19], [27].

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. VITAL

**Participants:** Salvatore Guzzo Bonifacio, Valeria Loscri, Nathalie Mitton [correspondant], Riccardo Petrolo.

Title: Virtualized programmable InTerfAces for innovative cost-effective IoT depLoyments in smart cities

Programm: FP7

Duration: September 2013 - August 2016

Coordinator: National University of Ireland Galway (NUIG)

Partners:

Research and Education Laboratory in Information Technologies (Greece)

Atos Spain (Spain)  
Camden Town Center (United Kingdom)  
Images & Co (United Kingdom)  
Istanbul Metropolitan Municipality (Turkey)  
Istanbul Teknik Universitesi (Turkey)  
National University of Ireland, Galway (Ireland)  
Santer Reply Spa (Italy)  
Singularlogic Anonymi Etairia Pliroforiakon Sistimaton Kai Efarmogon Pliroforikis (Greece)

Inria contact: Nathalie Mitton

Internet-of-Things (IoT) applications are currently based on multiple architectures, standards and platforms, which have led to a highly fragmented IoT landscape. This fragmentation is evident in the area of smart cities, which typically comprise several technological silos (i.e. IoT systems that have been developed and deployed independently). Nowadays there is a pressing need to remove these silos in order to allow cities to share data across systems and coordinate processes across domains, thereby essentially improving sustainability and quality of life. In response to this need, VITAL will realize a radical shift in the development, deployment and operation of IoT applications, through introducing an abstract virtualized digital layer that will operate across multiple IoT architectures, platforms and business contexts. Specifically, VITAL will provide platform and business context agnostic access to Internet-Connected-Objects (ICO). Moreover, it will research virtualized filtering, complex event processing (CEP) and business process management mechanisms, which will be operational over a variety of IoT architectures/ecosystems. The mechanisms will compromise the diverse characteristics of the underlying ecosystems, thereby boosting interoperability at the technical and business levels. VITAL will also provide development and governance tools, which will leverage the project's interfaces for virtualized access to ICOS. VITAL will allow solution providers to (re)use a wider range of data streams, thereby increasing the scope of potential applications. It will also enable a more connected/integrated approach to smart city applications development, which will be validated in realistic deployments in London and Istanbul. The partners will contribute and adapt a host of readily available urban infrastructures, IoT platforms and novel IoT applications, which will ease the accomplishment of the project's goals based on an optimal value for EC money. Publications in 2015 in the framework of this project are: [7], [16], [18].

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### 9.4.1.1. PREDNET

**Participants:** Nathalie Mitton [correspondant], Viktor Toldov, Julien Vandaele.

Title: Predator network

Type: LIRIMA

Duration: January 2013 - December 2016

See also: <https://iww.inria.fr/prednet/en/>

Abstract: PREDNET (PREDator adhoc NETwork) proposes to do research on the most suitable topology and subsequent deployment of a wireless sensor network for sparsely populated outlying rural and wilderness areas, for effective monitoring and protection of resources and ecosystems. This collaboration gave birth to joint project submission, joint conference organization and several publications, among them for 2015.

## 9.4.2. Inria International Partners

### 9.4.2.1. Declared Inria International Partners

Università Mediterranea di Reggio Calabria (UNIC) (Italy)

Objective of this collaboration is the design of an innovative architecture that enables autonomic and decentralized fruition of the services offered by the network of smart objects in many heterogeneous and dynamic environments, in a way that is independent of the network topology, reliable and flexible. The result is an 'ecosystem' of objects, self-organized and self-sustained, capable of making data and services available to the users wherever and whenever required, thus supporting the fruition of an 'augmented' reality thanks to a new environmental and social awareness. This collaboration gave birth to the PALMARES project (see section International programs), students and researchers exchanges (see section international visits) and joint publications, among them for 2015: [4], [3].

### 9.4.2.2. Informal International Partners

#### Southern University, China

The purpose of this collaboration is to study the green (or energy-efficient) communication problem in vehicular ad hoc networks (VANETs) and the application of vehicular network communication in green transportation. It gave birth to joint project submission, joint conference organization (UIC 2016) and several publications, among them for 2015: [9].

### 9.4.2.3. PhD co-supervision

**Participants:** Nathalie Mitton [correspondant], Mouna Rekik.

Since January 2013, Nathalie Mitton co-supervises Mouna Rekik as a PhD student with Pr Zied Chtourou from Université de Sfax, Tunisia. Her topic is about swarm intelligence based multi-path geographic routing for wireless sensor and actuator networks.

This work has led to the following publications in 2015: [22], [23], [24], [25].

## 9.4.3. Participation In other International Programs

### 9.4.3.1. CROMO

**Participants:** Valeria Loscri, Nathalie Mitton [correspondant], Riccardo Petrolo, Tahiry Razafindralambo.

Title: Crowd Data In the mobile cloud)

Duration: January 2015 - December 2019

CroMo (Crowd Data In the mobile cloud) is a submission to the CAPES-COFECUB project call lead by Inria from the French side and University of Rio de Janeiro from Brazilian Side. Other partner institutions are Université Pierre et Marie Curie and Université de la Rochelle.

Mobile cloud computing is an emerging paradigm to improve the quality of mobile applications by transferring part of the computational tasks to the resource-rich cloud. The multitude data sources combined with the known difficulties of wireless communications represent an important issue for mobile cloud computing. Therefore, the additional computational power added by the cloud has to deal with the constraints of the wireless medium. One could imagine a situation where different sensors collect data and require intensive computation. This data must be transmitted at high rates before becoming stale. In this case, the network becomes the main bottleneck, not the processing power or storage size. To circumvent this issue, different strategies can be envisioned. As usual alternatives, wireless data rates must be increased or the amount of data sent to the cloud must be reduced. CROMO tackles challenges from all these three components of the mobile clouds (data generation, collect and processing) to then integrate them as a whole enhanced mobile cloud with improved network performances in terms of delay, energy consumption, availability, and reliability.

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

Several researchers have visited our group in 2015, mainly from our partner universities but not only:

- Zied Chtourou, Univ. Sfax, Tunisia, March 2015
- Sajid Mubashir Sheikh, Univ. Stellenbosch, South Africa, July-August 2015
- Arun Sen, Arizona State University, USA, June-Nov 2015
- OP Vyas, Indian Institute of Information Technology, India July 2015
- Riaan Wolhuter, Univ. Stellenbosch, South Africa, July 2015

#### 9.5.1.1. Internships

We have hosted and supervised several master students. Some came to run their master internship in our lab, like

Ana Garcia Alcala from University of Lille (4 months), Mohamed El Amine Seddik from Telecom Lille (6 months), Ayoub El Yagoubi (4 months).

Other students have visited us from our partner universities in the framework of the joint project we run together. This is the case for Solomon Peterus Le Roux (2 months) who came from Stellenbosch university, South Africa, in the framework of the PredNET program and Anup Bhattacharjee from IIIT Allahabad, India (2 months).

### 9.5.2. Visits to International Teams

#### 9.5.2.1. Research stays abroad

- Nathalie Mitton visited IIIT Allahabad, India for 2 weeks in March 2015.
- Riccardo Petrolo visited UFRJ, Brasil for 2 months (Oct-dec 2015).

## 10. Dissemination

### 10.1. Promoting Scientific Activities

#### 10.1.1. Scientific events organisation

##### 10.1.1.1. General chair, scientific chair

- Valeria Loscri is/was (co)general chair for SwanSity 2015 and PACS 2015, of the special track "Body Area NanoNETworks: Electromagnetic, Materials and Communications (BANN-EMC)" in Body Area Networks conference.
- Aziz Mbacke is publicity chair for AdHocNow 2016.
- Nathalie Mitton is/was (co)general chair for AdHocNow 2016, Cloudification of IoT 2015, AdHoc-Nets 2015 and Inter-IoT 2015.
- Nathalie Mitton was demo chair for MobiCom 2015.
- Riccardo Petrolo is publicity chair for AdHocNets 2015 and web chair for AdHocNow 2016.
- Jean Razafimandimby Anjalalaina, was Publicity Chair for IoTIP 2015.
- Viktor Toldov is publicity chair for IndiaCom 2015.

##### 10.1.1.2. Member of the organizing committees

- The full team organizes AdHocNow 2016.

#### 10.1.2. Scientific events selection

##### 10.1.2.1. Chair of conference program committees

- Valeria Loscri is co-program chairs for AdHocNow 2016 and Member of the IEEE SMC (Systems, Man and Cybernetics Society) TC on "Interactive and Wearable Computing and Devices".
- Nathalie Mitton was co-program chair of the summer school RESCOM 2015 and of the RESCOM community days in January 2016.
- Nathalie Mitton is co-program chair for AdHocNow 2016, IEEE CSE 2016, SmartComp 2016, UIC 2016, VTC-Spring 2016, ICC 2016, NOMS 2015.

#### *10.1.2.2. Member of the conference program committees*

- Valeria Loscri is/was in the Technical Program Committee (TPC) of MoWNet' 15/16, IDCS 2015/16, SWIT-Health 2015, HPCC 2015, WiMob' 2015, Ntms 2015, IoTIP' 15, IoT2015, ICARSC 2015,
- Nathalie Mitton is/was in the Technical Program Committee (TPC) of Algotel 2015, NOMS 2015, ICC 2015.
- Tahiry Razafindralambo is/was in the Technical Program Committee (TPC) of Globecom 2015.

#### *10.1.3. Journal*

- Valeria Loscri is Co-editor of SPART, special Issue on Signal Processing Algorithms for Real-Time Sensing by Means of Wireless Sensor Networks.
- Valeria Loscri is Co-editor in the Special Issue on Smart Wireless Access Networks and Systems For Smart Cities, Elsevier Ad Hoc Networks.
- Valeria Loscri is Co-editor for the book MIoT2015, Management of Cyber Physical Objects in the Future Internet of Things on behalf of Springer.
- Valeria Loscri is a member of the 'Research Group on IoT Communications and Networking Infrastructure' at ComSoc Communities.
- Nathalie Mitton is editorial board members of AHSWN since 2011.
- Nathalie Mitton is editorial board member of Adhoc Networks since 2012.
- Nathalie Mitton is editorial board member of IET-WSS since 2013.
- Nathalie Mitton is editorial board member of ComSoc MMTC e-letter since 2014.

#### *10.1.4. Invited talks*

- Valeria Loscri was invited speaker at "Cloudification of the Internet of Things - CIoT" conference in Paris in June 2015.
- Valeria Loscri gave a talk at ICT2B "Innovation Runway Event" in Frankfurt, to present Vital project (February 2015).
- Valeria Loscri gave a talk at ICT2B "Venture Academy Event", in Chaldiki, Greece (June 2015).
- Nathalie Mitton was invited speaker at the French-India Architecture and Technological Trends and Issues in Indiacom in New Delhi in March 2015.
- Nathalie Mitton was invited speaker at IIIT Allahabad at the event on Smart Cities in Allahabad in March 2015.
- Nathalie Mitton was invited speaker at Rencontres Inria Industries in San Francisco in May 2015.
- Nathalie Mitton was invited speaker at BIS meeting in Berkeley in May 2015.
- Nathalie Mitton was invited speaker at the Inria-Mexico meeting in Mexico in June 2015.

#### *10.1.5. Scientific expertise*

Nathalie Mitton is an elected member of the evaluation community of Inria. She has acted as a reviewer for ANRT and ANR project submissions. She is also member of the scientific committees of the competitiveness cluster of MATIKEN and for CITC (International Contactless Technologies Center).

### 10.1.6. Research administration

Nathalie Mitton is a member of the Steering Committee of the GDR Rescom.

## 10.2. Teaching - Supervision - Juries

### 10.2.1. Teaching

#### E-learning

Mooc, Nathalie Mitton, "Villes intelligentes : défis technologiques et sociétaux" , 5-week mooc by the IPL CityLab@Inria team, FUN, Inria, to open in January 2016

Master : Roudy Dagher, Objets Communicants, 24h (Mineure Habitat Intelligent), Ecole des Mines de Douai, France.

Master: Valeria Loscri, Connected Objects, 24h eqTD (Engineer), Ecole des Mines, Douai

Master: Valeria Loscri, Telecom, 6h supervision TP (Engineer), Paris Telecom

Master : Nathalie Mitton, Wireless sensor networks, 36h eqTD (Master TIIR and MINT), Université Lille 1 and Telecom Lille 1, France

Bsc: Nathalie Mitton, Contactless technologies, 20h eqTD, Université de Valenciennes, France

BSC: Riccardo Petrolo, Réseaux Informatique, 36h TP and TD (Licence Info), Université Lille 1, France

BSC: Riccardo Petrolo, Technologies du Web, 36h TP and TD (Licence 1), Université Lille 1, France

Master : Viktor Toldov, Systèmes Numériques (VHDL), 18h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Systèmes Numériques (Projet VHDL), 15h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Communication numérique (Communication en bande transposée), 6h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Communication numérique (Projet), 10h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Technologie de l'électronique numérique et du signal, 25.5h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Réseaux d'Objets Communicants (Projet), 15h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Signal et Communication (Signaux déterministes), 3h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Signal et Communication (Signaux aléatoires), 4.5h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Viktor Toldov, Projets Scientifiques et Technologiques 10h eqTD (Formation d'ingénieur), Télécom Lille, France

Licence : Jean Razafimandimby, Algorithms and Programming, 30h eqTD, Université Lille 1, France

Master : Tahiry Razafindralambo, Réseaux d'Objets Communicants (Projet), 9h eqTD (Formation d'ingénieur), Télécom Lille, France

Master : Tahiry Razafindralambo, Qualité de Service, 7h eqTD (Formation d'ingénieur - SPIRALE), Télécom Lille - , France

### 10.2.2. Supervision

PhD defended on Dec 15th, 2015: Natale Guzzo, Auto - organisation et économie d'énergie dans un réseau sans fil de surveillance de fret, Université Lille 1, 2013-2015, Nathalie Mitton

PhD defended on Oct 6th 2015: Roudy Dagher, Géolocalisation en environnement réel, extérieur et intérieur avec réseau de capteurs, Université Lille 1, 2013-2015, Nathalie Mitton

PhD in progress: Riccardo Petrolo, Internet of Things and Smart Cities, Université Lille 1, 2013-2016, Nathalie Mitton and Valeria Loscri

PhD in progress: Viktor Toldov, : Interférence et consommation dans les réseaux de capteurs, Université Lille 1, 2013-2016, Nathalie Mitton and Laurent Clavier

PhD in progress: Mouna Rekik, geographic multi path routing protocol based on swarm intelligence for wireless sensor and actuator networks in the context of Smart Grids, co-supervision Université Lille 1 and University of Sfax (Tunisia), 2013-2017, Nathalie Mitton and Zied Chtourou

PhD in progress: Jean Razafimandimby, Distibuted Cooperation and Communication among Heterogeneous Devices, Université Lille 1, 2014-2017, Tahiry Razafindralambo and Valeria Loscri

PhD in progress: Aziz Mbacke, Smart Deployment of heterogeneous sensors and RFID in a Smart City, Université Lille 1, 2015-2018, Nathalie Mitton and Hervé Rivano (Urbanet)

PhD in progress: Jad Nassar, Ubiquitous networks for smart grids, Université Lille 1, 2015-2018, Nathalie Mitton and Nicolas Gouvy (HEI)

### 10.2.3. Juries

- Nathalie Mitton was reviewer of the following PhD thesis:
  - Mario Antonio Gasperin Zancanaro, UPMC, January 2015
  - Benjamin Billet, Inria Rocquencourt, 19 march 2015
  - Farouk Mezghani, University of Toulouse, 9 october 2015
  - Malisa Vucinic, University of Grenoble, 17 november 2015
- Nathalie Mitton was member of the PhD defense committee of Filippo Rebecchi, 18 september 2015, UPMC.
- Nathalie Mitton was member of the Inria CR2 Lille and Nancy competition selection committee.

## 10.3. Popularization

- Salvatore Guzzo Bonifacio gave a talk on "Introduction to Wireless Sensor Networks" in the framework of "Fête de la Science".
- Nathalie Mitton gave a talk on "Introduction to RFID" to Terminales S a in the framework of "Fête de la Science".
- Nathalie Mitton gave a talk at the BIS conference on Smart Cities in Berkeley in May 2015.
- Nathalie Mitton presented the wireless networks to ISN classes on March 2015.
- Nathalie Mitton gave a talk on the Connected bike to the BeyondLab PlugTest on March 2015.
- Jean Razafimandimby gave a talk on "Can robots cooperate?" to BTS a in the framework of "Fête de la Science".
- Viktor Toldov gave a talk on "Introduction to Wireless Sensor Networks" in the framework of "Fête de la Science".
- Viktor Toldov gave a talk on the PREDNET project to the BeyondLab PlugTest on March 2015.
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