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Team URBANET

Réseaux capillaires urbains

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Team URBANET

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2. Overall Objectives

2.1. Introduction

Team UrbaNet's overall objectives are to study and characterize the architectures of urban capillary wireless networks and to propose mechanisms and protocols that are designed for the specific settings of the urban environment. It requires taking into account constraints on the node deployment, heterogeneous and dynamic wireless connectivity, and requirements yielded by the usage of the city and the societal trends. Our methodology consists in combining formal verification and combinatorial optimization methods with simulation based and analytical performance assessments to guide the development of relevant mechanisms.

3. Research Program

3.1. Capillary networks

The definition of Smart Cities is still constantly redefined and expanded so as to comprehensively describe the future of major urban areas. The Smart City concept mainly refers to granting efficiency and sustainability in densely populated metropolitan areas while enhancing citizens' life and protecting the environment. The Smart City vision can be primarily achieved by a clever integration of ICT in the urban tissue. Indeed, ICTs are enabling an evolution from the current duality between the "real world" and its digitalized counterpart to a continuum in which digital contents and applications are seamlessly interacting with classical infrastructures and services. The general philosophy of smart cities can also be seen as a paradigm shift combining the Internet of Things (IoT) and Machine-to-Machine (M2M) communication with a citizen-centric model, all together leveraging massive data collected by pervasive sensors, connected mobile or fixed devices, and social applications.

The fast expansion of urban digitalization yields new challenges that span from social issues to technical problems. Therefore, there is a significant joint effort by public authorities, academic research communities and industrial companies to understand and address these challenges. Within that context, the application layer, i.e., the novel services that ICT can bring to digital urban environments, have monopolized the attention. Lower-layer network architectures have gone instead quite overlooked. We believe that this might be a fatal error, since the communication network plays a critical role in supporting advanced services and ultimately in making the Smart City vision a reality. The UrbaNet project deals precisely with that aspect, and the study of network solutions for upcoming Smart Cities represents the core of our work.

Most network-related challenges along the road to real-world Smart Cities deal with efficient mobile data communication, both at the backbone and at the radio access levels. It is on the latter that the UrbaNet project is focused. More precisely, the scope of the project maps to that of capillary networks, an original concept we define next.

The capillary networking concept represents a unifying paradigm for wireless last-mile communication in smart cities. The term we use is reminiscent of the pervasive penetration of different technologies for wireless communication in future digital cities. Indeed, capillary networks represent the very last portion of the data distribution and collection network, bringing Internet connectivity to every endpoint of the urban tissue in the same exact way capillary blood vessels bring oxygen and collect carbon dioxide at tissues in the human body. Capillary networks inherit concepts from the self-configuring, autonomous, ad hoc networks so extensively studied in the past decade, but they do so in a holistic way. Specifically, this implies considering multiple technologies and applications at a time, and doing so by accounting for all the specificities of the urban environment.

3.2. Specific issues and new challenges of capillary networks

Capillary networks are not just a collection of independent wireless technologies that can be abstracted from the urban environment and/or studied separately. That approach has been in fact continued over the last decade, as technologies such as sensor, mesh, vehicular, opportunistic, and – generally speaking – M2M networks have been designed and evaluated in isolation and in presence of unrealistic mobility and physical layer, simplistic deployments, random traffic demands, impractical application use cases and non-existent business models. In addition, the physical context of the network has a significant impact on its performances and cannot be reduced to a simple random variable. Moreover, one of the main element of a network never appears in many studies: the user. To summarize, networks issues should be addressed from a user- and context-centric perspective.

Such abstractions and approximations were necessary for understanding the fundamentals of wireless network protocols. However, real world deployments have shown their limits. The finest protocols are often unreliable and hardly applicable to real contexts. That also partially explains the marginal impact of multi-hop wireless technologies on today's production market. Industrial solutions are mostly single-hop, complex to operate, and expensive to maintain.

In the UrbaNet project we consider the capillary network as an ensemble of strongly intertwined wireless networks that are expected to coexist and possibly co-operate in the context of arising digital cities. This has three major implications:

- Each technology contributing to the overall capillary network should not be studied apart. As a matter of fact, mobile devices integrate today a growing number of sensors (e.g., environment sensing, resource consumption metering, movement, health or pollution monitoring) and multiple radio interfaces (e.g., LTE, WiFi, ZigBee,. . .), and this is becoming a trend also in the case of privately owned cars, public transport vehicles, commercial fleets, and even city bikes. Similarly, access network sites tend to implement heterogeneous communication technologies so as to limit capital expenses. Enabling smart-cities needs a dense sensing of its activities, which cannot be achieved without multi-service sensor networks. Moreover, all these devices are expected to inter-operate so as to make the communication more sustainable and reliable. Thus, the technologies that build up the capillary network shall be studied as a whole in the future.
- The capillary network paradigm necessarily accounts for actual urban mobility flows, city land-use layouts, metropolitan deployment constraints, and expected activity of the citizens. Often, these specificities do not arise from purely networking features, but relate to the study of city topologies and road layouts, social acceptability, transportation systems, energy management, or urban economics. Therefore, addressing capillary network scenarios cannot but rely on strong multidisciplinary interactions.
- Digital and smart cities are often characterized by arising M2M applications. However, a city is, before all, the gathering of citizens, who use digital services and mobile Internet for increasing their quality of life, empowerment, and entertainment opportunities. Some data flows should be gathered to, or distributed from, an information system. Some other should be disseminated to a geographically or time constrained perimeter. Future usage may induce peer-to-peer like traffics. Moreover these services are also an enabler of new usages of the urban environment. Solutions built within the capillary network paradigm have to manage this heterogeneity of traffic requirements and user behaviors.

By following these guidelines, the UrbaNet ambition is to go one step beyond traditional approaches discussed above. The capillary network paradigm for Smart Cities is tightly linked to the specificities of the metropolitan context and the citizens' activity. Our proposal is thus to re-think the way capillary network technologies are developed, considering a broader and more practical perspective.

3.3. Characterizing urban networks

Our first objective is to understand and model those properties of real-world urban environments that have an impact on the design, deployment and operation of capillary networks. It means to collect and analyze data from actual deployments and services, as well as testbeds experiments. These data have then to be correlated with urban characteristics, e.g. topography, density of population and activities. The objective is to deduce analytical models, simulations and traces of realistic scenarios that can be leveraged afterward. We structure the axis into three tasks that correspond to the three broad categories of networking aspects affected by the urban context.

- **Topological characteristics**. Nowadays, the way urban wireless network infrastructures are typically represented in the literature is dissatisfying. As an example, wireless links are mostly represented as symmetric, lossless channels whose signal quality depends continuously on the distance between the transmitter and the receiver. No need to say, real-world behaviors are very far from these simplified representations. Another example, topologies are generally modeled according to deterministic (e.g., regular grids and lattices, or perfect hexagonal cell coverages) or stochastic (e.g., random uniform distributions over unbound surfaces) approaches. These make network problems mathematically tractable and simulations easier to set up, but are hardly representative of the layouts encountered in the real world. Employing simplistic models helps understanding some fundamental principles but risks to lead to unreliable results, both from the viewpoint of the network architecture design and from that of its performance evaluation. It is thus our speculation that the actual operations and the real-world topologies of infrastructured capillary networks are key to the successful deployment of these technologies, and, in this task, we aim at characterizing them. To that end, we leverage existing collaborations with device manufacturers (Alcatel-Lucent, HiKob) and operators (Coronis, Orange), as well as collaboration such as the Sense City project and testbed experiments, in order to provide models that faithfully mimic the behavior of real world network devices. The goal is to understand the important features of the topologies, including, e.g., their overall connectivity level, spatial density, degree distribution, regularity, etc. Building on these results, we try to define network graph models that reproduce such major features and can be employed for the development and evaluation of capillary network solutions.

- **Mobilities**. We aim at understanding and modeling the mobile portion of capillary networks as well as the impact of the human mobility on the network usage. Our definition of "mobile portion" includes traditional mobile users as well as all communication-enabled devices that autonomously interact with Internet-based servers and among themselves. There have been efforts to collect real-world movement traces, to generate synthetic mobility dataset and to derive mobility models. However, real-world traces remain limited to small scenarios or circumstantial subsets of the users (e.g., cabs instead of the whole road traffic). Synthetic traces are instead limited by their scale and by their level of realism, still insufficient. Finally, even the most advanced models cannot but provide a rough representation of user mobility in urban areas, as they do not consider the street layout or the human activity patterns. In the end, although often deprecated, random or stochastic mobility models (e.g., random walks, exponential inter-arrivals and cell residence times) are still the common practice. We are well aware of the paramount importance of a faithful representation of device and user mobility within capillary networks and, in order to achieve it, we leverage a number of realistic sources, including Call Detail Records (CDR) collected by mobile operators, Open Data initiatives, real-world social network data, and experiments. We collect data and analyze it, so as to infer the critical properties of the underlying mobility patterns.
- **Data traffic patterns**. The characterization of capillary network usages means understanding and modeling when, where and how the wireless access provided by the diverse capillary network technologies is exploited by users and devices. In other words, we are interested in learning which applications are used at different geographical locations and day times, which urban phenomena generate network usage, and which kind of data traffic load they induce on the capillary network. Properly characterizing network usages is as critical as correctly modeling network topology and mobility. Indeed, the capillary networks being the link directly collecting the data from end devices, we cannot count on statistical smoothing which yields regular distributions. Unfortunately, the common practice is to consider, e.g., that each user or device generates a constant data traffic or follows on/off models, that the offered load is uniform over space and does not vary over time, that there is small difference between uplink and downlink behaviors, or that source/destination node pairs are randomly distributed in the network. We try to go further on the specific scenarios we address, such as smart-parking, floating car data, tele-metering, road traffic management of pollution detection. To that end, we collect real-world data, explore it and derive properties useful to the accurate modeling of content consumption.

3.4. Autonomic networking protocols

While the capillary networks concept covers a large panel of technologies, network architectures, applications and services, common challenges remain, regardless the particular choice of a technology or architecture.

Our record of research on spontaneous and multi-hop networks let us think that autonomic networking appears as the main issue: the connectivity to Internet, to cyber-physical systems, to Information Systems should be transparent for the user, context-aware and location-aware. To address these challenges, a capillary network model is required. Unfortunately, very few specific models fit this task today. However, a number of important, specific capillary networks properties can already be inferred from recent experiments: distributed and localized topologies, very high node degree, dynamic network diameter, unstable / asymmetric / non-transitive radio links, concurrent topologies, heterogeneous capabilities, etc. These properties can already be acknowledged in the design of networking solutions, and they are particularly challenging for the functioning of the MAC layer and QoS support. Clearly, capillary networks provide new research opportunities with regard to networking protocols design.

- **Self-* protocols**. In this regard, self-configuration, self-organization and self-healing are some of the major concerns within the context of capillary networks. Solving such issues would allow spontaneous topologies to appear dynamically in order to provide a service depending of the location and the context, while also adapting to the interactions imposed by the urban environment. Moreover, these mechanisms have the capacity to alleviate the management of the network and the deployment engineering rules, and can provide efficient support to the network dynamics due to user mobility, environment modifications, etc. The designed protocols have to be able to react to traffic requests and local node densities. We address such self-adaptive protocols as a transversal solution to several scenarios, e.g. pollution monitoring, smart-services depending on human activities, vehicle to infrastructure communications, etc. In architectures where self-* mechanisms govern the protocol design, both robustness and energy are more than ever essential challenges at the network layer. Solutions such as energy-harvesting can significantly increase the network lifetime in this case, therefore we investigate their impact on the mechanisms at both MAC and network layers.
- **Quality of service issues**. The capillary networks paradigm implies a simultaneous deployment of multiple wireless technologies, and by different entities (industry, local community, citizens). This means that some applications and services can be provided concurrently by different parts of the capillary network, while others might require the cooperation of multiple parties. The notion of Service Level Agreement (SLA) for traffic differentiation, quality of service support (delay, reliability, etc.) is a requirement in these cases for scalability purposes and resource sharing. We contribute to a proper definition of this notion and the related network mechanisms in the settings of low power wireless devices. Because of the urban context, but also because of the wireless media itself, network connectivity is always temporary, while applications require a delivery ratio close to 100%. We investigate different techniques that can achieve this objective in an urban environment.
- **Data impact**. Capillary networks suffer from low capacity facing the increasing user request. In order to cope with network saturation, a promising strategy is to consider the nature of the transmitted data in the development of the protocols. Data aggregation and data gathering are two concepts with a major role to play in this context of limited capacity. In particular, combining local aggregation and measurement redundancy for improving on data reliability is a promising idea, which can also be important for energy saving purposes. Even if the data flow is well known and regular, e.g. temperature or humidity metering, developing aggregation schemes tailored to the constraints of the urban environment is a challenge we address within the UrbaNet team. Many urban applications generate data which has limited spatial and temporal perimeters of relevance, e.g. smart-parking applications, community information broadcasting, etc. When solely a spatial range of relevance is considered, the underlying mechanisms are denoted “geocasting”. We also address these spatio-temporal constraints, which combine geocasting approaches with real-time techniques.

3.5. Optimizing cellular network usage

The capacity of cellular networks, even those that are now being planned, does not seem able to cope with the increasing demands of data users. Moreover, new applications with high bandwidth requirements are also foreseen, for example in the intelligent transportation area, and an exponential growth in signaling traffic is expected in order to enable this data growth. Cumulated with the lack of available new spectrum, this leads to an important challenge for mobile operators, who are looking at both licensed and unlicensed technologies for solutions. The usual strategy consists in a dramatic densification of micro-cells coverage, allowing both to minimize the transmission power of cellular networks as well as to increase the network capacity. However, this solution has obvious physical limits, which we work on determining, and we propose exploiting the capillarity of network interfaces as a complementary solution.

- **Green cellular network**. Increasing the density of micro-cells means multiplying the energy consumption issues. Indeed, the energy consumption of actual LTE eNodeBs and relays, whatever their state, idle, transmitting or receiving, is a major and growing part of the access network energy consumption. For a sustainable deployment of such micro-cell infrastructures and for a significative decrease of the overall energy consumption, an operator needs to be able to switch off cells when they are not absolutely needed. The densification of the cells induces the need for an autonomic control of the on/off state of cells. One solution in this sense can be to adapt the WSN mechanisms to the energy models of micro-cells and to the requirements of a cellular network. The main difficulty here is to be able to adapt and assess the proposed solutions in a realistic environment (in terms of radio propagation, deployment of the cells, user mobility and traffic dynamics).
- **Offloading**. Offloading the cellular infrastructure implies taking advantage of the wealth of connectivity provided by capillary networks instead of relying solely on 4G connectivity. Cellular operators usually possess an important ADSL or cable infrastructure for wired services, the development of femtocell solutions thus becomes very popular. However, while femtocells can be an excellent solution in zones with poor coverage, their extensive use in areas with a high density of mobile users leads to serious interference problems that are yet to be solved. Taking advantage of capillarity for offloading cellular data relies on using IEEE 802.11 Wi-Fi (or other similar technologies) access points or direct device-to-device communications. The ubiquity of Wi-Fi access in urban areas makes this solution particularly interesting, and many studies have focused on its potential. However, these studies fail to take into account the usually low quality of Wi-Fi connections in public areas, and they consider that a certain data rate can be sustained by the Wi-Fi network regardless of the number of contending nodes. In reality, most public Wi-Fi networks are optimized for connectivity, but not for capacity, and more research in this area is needed to correctly assess the potential of this technology. Direct opportunistic communication between mobile users can also be used to offload an important amount of data. This solution raises a number of major problems related to the role of social information and multi-hop communication in the achievable offload capacity. Moreover, in this case the business model is not yet clear, as operators would indeed offload traffic, but also lose revenue as direct ad-hoc communication would be difficult to charge and privacy issues may arise. However, combining hotspot connectivity and multi-hop communications is an appealing answer to broadcasting geo-localized informations efficiently.

4. Application Domains

4.1. Smart urban infrastructure

Unlike the communication infrastructure that went through a continuous development in the last decades, the distribution networks in our cities including water, gas and electricity are still based on 19th century infrastructure. With the introduction of new methods for producing renewable but unpredictable energy and with the increased attention towards environmental problems, modernizing distribution networks became one of the major concerns in the urban world. An essential component of these enhanced systems is their integration with information and communications technology, the result being a smart distribution infrastructure, with improved efficiency and reliability. This evolution is mainly based on the increased deployment of automatic equipment and the use of machine-to-machine and sensor-to-actuator communications that would allow taking into account the behavior and necessities of both consumers and suppliers

Another fundamental urban infrastructure is the transportation system. The progress made in the transportation industry over the last century has been an essential factor in the development of today's urban society, while also triggering the birth and growth of other economic branches. However, the current transportation system has serious difficulties coping with the continuous growth in the number of vehicles, especially in an urban environment. As a major increase in the capacity of a city road infrastructure, already in place for tens or even hundreds of years, would imply dissuasive costs, the more realistic approach is to optimize the use of the existing transportation system. As in the case of distribution networks, the intelligence of the system can be achieved through the integration of information and communication capabilities. However, for smart transportation the challenges are somehow different, because the intelligence is no longer limited to the infrastructure, but propagates to vehicles themselves. Moreover, the degree of automation is reduced in transportation systems, as most actions resulting in reduced road congestion, higher reliability or improved safety must come from the human driver (at least in the foreseeable future)

Finally, smart spaces are becoming an essential component of our cities. The classical architecture tools used to design and shape the urban environment are more and more challenged by the idea of automatically modifying private and public spaces in order to adapt to the requirements and preferences of their users. Among the objectives of this new urban planning current, we can find the transformation of the home in a proactive health care center, fast reconfigurable and customizable workplaces, or the addition of digital content in the public spaces in order to reshape the urban scene. Bringing these changing places in our daily lives is conditioned by a major shift in the construction industry, but it also involves important advancements in digital infrastructure, sensing, and communications

4.2. Urban participatory sensing

Urban sensing can be seen as the same evolution of the environment digitalization as social networking has been for information flows. Indeed, besides dedicated and deployed sensors and actuators, still required for specific sensing operations such as the real-time monitoring of pollution levels, there is a wide range of relevant urban data that can be collected without the need for new communication infrastructures, leveraging instead on the pervasiveness of smart mobile terminals. With more than 80% of the population owning a mobile phone, the mobile market has a deeper penetration than electricity or safe drinking water. Originally designed for voice transmitted over cellular networks, mobile phones are today complete computing, communication and sensing devices, offering in a handheld device multiple sensors and communication technologies.

Mobile devices such as smartphones or tablets are indeed able to gather a wealth of informations through embedded cameras, GPS receivers, accelerometers, and cellular, WiFi and bluetooth radio interfaces. When collected by a single device, such data may have small value per-se, however its fusion over large scales could prove critical for urban sensing to become an economically viable mainstream paradigm.

This is even more true when less traditional mobile terminals are taken into account: privately-owned cars, public transport means, commercial fleets, and even city bikes are starting to feature communication capabilities and the Floating Car Data (FCD) they generate can bring a dramatic contribution to the cause of urban sensing. Indeed, other than enlarging the sensing scope even further, e.g., through Electronic Control Units (ECUs), these mobile terminals are not burdened by strong energy constraints and can thus significantly increase the granularity of data collection. This data can be used by authorities to improve public services, or by citizens who can integrate it in their choices. However, in order to kindle this hidden information, important problems related to data gathering, aggregation, communication, data mining, or even energy efficiency need to be solved.

4.3. User-centric services

Combining location awareness and data recovered from multiple sources like social networks or sensing devices can surface previously unknown characteristics of the urban environment, and enable important new services. As a few examples, one could think of informing citizens about often disobeyed (and thus risky) traffic signs, polluted neighborhoods, or queue waiting times at current exhibitions in the urban area.

Beyond letting their own devices or vehicles autonomously harvest data from the environment through embedded or onboard sensors, mobile users can actively take part in the participatory sensing process because they can, in return, benefit from citizen-centric services which aim at improving their experience of the urban life. Crowdsourcing applications have the potential to turn citizens into both sources of information and interactive actors of the city. It is not a surprise that emerging services built on live mobile user feedback are rapidly meeting a large success. In particular, improving everyone's mobility is probably one of the main services that a smart city shall offer to its inhabitants and visitors. This implies providing, through network broadcast data or urban smart-furniture, an accurate and user-tailored information on where people should head in order to find what they are looking for (from a specific kind of shop to a free parking slot), on their current travel time estimates, on the availability of better alternate means of transport to destination. Depending on the context, such information may need to be provided under hard real-time constraints, e.g., in presence of road accidents, unauthorized public manifestations, or delayed public transport schedules.

In some cases, information can also be provided to mobile users so as to bias or even enforce their mobility: drivers can be alerted of the arrival of an emergency vehicle so that they leave the leftmost lane available, or participants leaving vast public events can be directed out of the event venue through diverse routes displayed on their smartphones so as to dynamically balance the pedestrian flows and reduce their waiting times.

5. Software and Platforms

5.1. WSNet

UrbaNet is an active contributor to WSnet (http://wsnet.gforge.inria.fr/), a discrete event simulator dedicated to large scale wireless networks developed and maintained by members of Inria and CITI lab. A major part of this contribution is represented by the implementation of state of the art protocols for medium access control and routing.

The WSNet simulation results obtained following this process are sometimes used as an input for another part of our development effort, which consists in prototype software based on the combination of CPLEX and AMPL for solving mixed integer linear programming problems with column generation.

5.2. TAPASCologne vehicular mobility dataset

Based on the data made available by the Institute of Transportation Systems at the German Aerospace Center (ITS-DLR), the dataset aims at reproducing, with a high level of realism, car traffic in the greater urban area of the city of Cologne, Germany. To that end, different state-of-art data sources and simulation tools are brought together, so to cover all of the specific aspects required for a proper characterization of vehicular traffic:

- The street layout of the Cologne urban area is obtained from the OpenStreetMap (OSM) database;
- The microscopic mobility of vehicles is simulated with the Simulation of Urban Mobility (SUMO) software;
- The traffic demand information on the macroscopic traffic flows across the Cologne urban area (i.e., the O/D matrix) is derived through the Travel and Activity PAtterns Simulation (TAPAS) methodology;
- The traffic assignment of the vehicular flows described by the TAPASCologne O/D matrix over the road topology is performed by means of Gawron's dynamic user assignment algorithm.

The resulting synthetic trace of the car traffic in a the city of Cologne covers a region of 400 square kilometers for a period of 24 hours, comprising more than 700.000 individual car trips. More information is available on the project website at http://kolntrace.project.citi-lab.fr/ .

6. New Results

6.1. Characterizing and measuring urban networks

Participants: Marco Fiore, Diala Naboulsi, Razvan Stanica, Sandesh Uppoor

6.1.1. Properties of urban vehicular traffic and implications on mobile networking.

The goal of Sandesh Uppoor's PhD thesis [4] was to model and understand the mobility dynamics of high-speed vehicular users and their effect on wireless network architectures in an urban environment. Given the importance of developing the study on a realistic representation of vehicular mobility, we first survey the most popular approaches for the generation of synthetic road traffic and discuss the features of publicly available vehicular mobility datasets. Using original travel demand information of the population of a metropolitan area (Cologne area, Germany), detailed road network data and realistic microscopic driving models, we propose a novel state-of-art vehicular mobility dataset that closely mimics the real-world road traffic dynamics in both time and space [25]. We then study the impact of such mobility dynamics from the perspective of wireless cellular network architecture in presence of a real-world base station deployment. In addition, by discussing the effects of vehicular mobility on autonomous network architecture, we hint at the opportunities for future heterogeneous network paradigms and demonstrate how incomplete representations of vehicular mobility may result in over-optimistic network connectivity and protocol performance [8].

Motivated by the time-evolving mobility dynamics observed in our original dataset, we also propose an on line approach to predict near-future macroscopic traffic flows. We analyze the parameters affecting the mobility prediction in an urban environment and unveil when and where network resource management is more crucial to accommodate the traffic generated by users on-board. Such studies unveil multiple opportunities in transportation management either for building new roads, installing electric charging points, or for designing intelligent traffic light systems, thereby contributing to urban planning.

6.1.2. Feasibility of multi-hop vehicular communications in an urban environment.

Despite the growing interest in a real-world deployment of vehicle- to-vehicle communication, many topological features of the resulting vehicular network remain largely unknown. We still lack a clear understanding of the level of connectivity achievable in large-scale urban scenarios, of the availability and reliability of connected multi-hop paths, and of the evolution of such features over daytime. In [14], we investigate how the instantaneous topology of the vehicular network would look like in the case of a typical middle-sized European city, using the example of the Cologne mobility trace. Through a complex network analysis, we unveil the low connectivity, availability, reliability and navigability of the network, and exploit our findings to derive network design and usage guidelines.

6.1.3. Investigating the accuracy of mobile urban sensing.

Community urban sensing is one of the emerging applications enabled by the growing popularity of mobile user devices, like smartphones and in-vehicle monitoring systems. Such devices feature sensing and wireless communication capabilities, which enable them to sample large-scale phenomena, like air pollution and vehicular traffic congestion, and upload these data to the Internet. In [10], we focus on the above scenario and investigate the level of accuracy that can be achieved in estimating the phenomenon of interest through a mobile crowdsourcing application. Specifically, we take a signal processing-based approach and leverage results on signal reconstruction from sets of irregularly spaced samples. We apply such results to a realistic scenario where samples are collected by vehicular and pedestrian users, and study the accuracy level of the phenomenon estimation as the penetration rate of the sensing application varies.

6.1.4. Analysis of mobile network call detail records.

The growing ubiquity of mobile communications has offered researchers new possibilities to understand human mobility over the last few years. In [22], we analyze Call Detail Records (CDR) made available within the context of the Orange D4D Challenge, focusing on calls of individuals in the city of Abidjan, Ivory Coast, over a period of five months. Our results illustrate how aggregated CDR can be used to tell apart typical and special mobility behaviors, and demonstrate how macroscopic mobility flows extracted from these cellular network data reflect the daily dynamics of a highly populated city. We discuss how these macroscopic mobility flows can help solve problems in developing urban areas.

6.2. Scalable solutions for capillary networks

Participants: Isabelle Augé-Blum, Jin Cui, Marco Fiore, Ochirkhand Erdene-Ochir, Alexandre Mouradian, Hervé Rivano, Razvan Stanica, Fabrice Valois

6.2.1. Real-time wireless sensor networks.

Critical applications for WSNs are emerging, with real-time and reliability requirements. Critical applications are applications on which depend human lives and the environment: a failure of a critical application can thus have dramatic consequences. We are especially interested in anomaly detection applications (forest fire detection, landslide detection, intrusion detection, etc), which require bounded end to end delays and high delivery ratio. Few WSNs protocols of the literature allow to bound end to end delays. Among the proposed solutions, some allow to effectively bound the end to end delays, but do not take into account the characteristics of WSNs (limited energy, large scale, etc). Others take into account those aspects, but do not give strict guaranties on the end to end delays. In this sense, the PhD thesis of Alexandre Mouradian [2] proposes a real-time anomaly detection solution composed of:

- A virtual coordinate system which allows to discriminate nodes in a 2-hop neighborhood and to bound the number of hops between any source and the sink.
- A cross-layer protocol for WSNs (named RTXP) based on the proposed virtual coordinate system. Thanks to these coordinates it is possible to introduce determinism in the accesses to the medium and to bound the hop-count, this allows to bound the end to end delay. RTXP adapts its duty-cycle to the traffic loads and uses an opportunistic routing scheme to increase its delivery ratio. We show, by simulation, that RTXP outperforms real-time protocols of the literature for anomaly detection in WSNs under harsh radio conditions.
- A real-time aggregation scheme to mitigate the alarm storm problem which causes collisions and congestion and thus limit the network lifetime. This scheme is also based on the virtual coordinate system and is used before RTXP in order to reduce the number of similar alarms converging toward the sink.

6.2.2. Formal verification of wireless sensor networks protocols.

WSN protocols used by critical applications must be formally verified in order to provide the strongest possible guaranties: simulations and tests are not sufficient in this context, formal proofs of compliance with the specifications of the application have to be provided.. Unfortunately the radio link is unreliable and it is thus difficult to give hard guarantees on the temporal behavior of the protocols. Indeed, a message may experience a very high number of retransmissions and the temporal guarantee can only be given with a certain probability. This probability must meet the requirements of the application. Network protocols have been successfully verified on a given network topology without taking into account unreliable links. Nevertheless, the probabilistic nature of radio links may change the topology (links which appear and disappear). Thus instead of a single topology we have a set of possible topologies, each topology having a probability to exist. In [12], we propose a method that produces the set of topologies, checks the property on every topology, and gives the probability that the property is verified. This technique is independent from the verification technique, i.e. each topology can be verified using any formal method which can give a “yes” or “no” answer to the question: “Does the model of the protocol respect the property?”. We apply this method on the f-MAC protocol. We use UPPAAL model checker as verification tool. We implement a tool that automatizes the process and thus show the feasibility of our proposition. We compare the results of the verification with simulation results. It appears that the verification is, as expected, conservative but not overly pessimistic compared to the simulated worst case. Besides we show that f-MAC is a reliable real-time protocol for WSNs (for up to 6 nodes), as we were not able to detect faults.

Moreover, in [2], a verification technique which mixes Network Calculus and Model Checking is proposed, in order to be both scalable and exhaustive. This technique consists in modeling the interaction of each node with the rest of the network with arrival curves and then to verify with UPPAAL that each node is capable of handling these interactions while meeting the deadlines. We apply this methodology in order to formally verify our pervious proposition, RTXP.

6.2.3. Reliability in wireless sensor networks.

WSN critical applications require the respect of time and reliability constraints. In [13], we provide a theoretical study of the reliability in WSNs. We define the reliability as the probability of success of an end-to-end transmission in the WSN. In this work, we use two radio propagation models : a basic model where the nodes have a set of neighbors they can communicate with, with a given probability, and the log-normal shadowing model, where probability of reception depends on the emitter-receiver distance. We determine the reliability of two routing schemes : unicast-based routing (classical routing) and broadcast-based routing (opportunistic routing). We conclude that the broadcast-based routing allows to reach a higher reliability than the unicast case. The main result is that we show the existence of a reliability bottleneck at the sink node in the case of the broadcast-based routing. We show that the addition of another sink improves the reliability of the network in this case.

6.2.4. Resiliency in wireless sensor networks.

Because of their open and unattended deployment, in possibly hostile environments, powerful adversaries can easily launch Denial-of-Service (Dos) attacks on wireless sensor networks, cause physical damage to sensors, or even capture them to extract sensitive information (encryption keys, identities, addresses, etc.). Consequently, the compromised node poses severe security and reliability concerns, since it allows an adversary to be considered as a legitimate node inside the network. To cope with these "insider" attacks, stemming from node compromise, "beyond cryptography" algorithmic solutions must be envisaged to complement the traditional cryptographic solutions. In this sense, in [1], we first propose the resiliency concept. Our goal is to propose a definition of the resiliency in our context (security of WSNs routing protocols) and a new metric to compare routing protocols. The originality of this metric is that we combine the graphical representation (qualitative information) with the aggregation method (quantitative information). We introduce a two dimensional graphical representation with multiple axes forming an equiangular polygon surface. This method allows to aggregate meaningfully several parameters and makes it easier to visually discern various trade-offs, thus greatly simplifying the process of protocol comparison.Secondly, we propose the protocol behaviors enhancing resiliency. Our proposition consists in three elements: (i) introduce random behaviors (ii) limit route length (iii) introduce data replication. Random behaviors increase uncertainty for an adversary, making the protocols unpredictable. Data replication allows route diversification between the sources and the sink, thus improving the delivery success and fairness. Limitation of the route length is necessary to reduce the probability of a data packet to meet a malicious insider along the route. The quantitative metric enables to propose a new resiliency taxonomy of WSNs routing protocols. According to this taxonomy, the gradient based routing is the most resilient when it is combined with the proposed behaviors. Thirdly, several variants of the gradient-based routing (classical and randomized) under more complex and realistic adversary model (several combined attacks) are considered to extend our simulations. Several values of bias are introduced to the randomized variants and two data replication methods (uniform and adaptive) are considered. Without attacks, the most biased variants without replications are the most efficient. However, under moderate attacks, the replication uniform is the most adapted, while under intense attacks, the replication adaptive is the most suitable. Finally, a theoretical study of the resiliency is introduced. We present an analytical study of the biased random walk routing under attacks. The influence of bias is evaluated and two replication methods that previously evaluated by simulations are considered. After presenting the delivery success and the energy consumption of all scenarios, we evaluate them with our resiliency metric. This study permits to confirm the results obtained with simulations and it shows that the bias is essential to enhance the resiliency of random routing.

6.2.5. Data aggregation in wireless sensor networks.

Data aggregation is a crucial problem in wireless sensor networks due to their constrained-energy and constrained-bandwidth nature. In [26], we highlight the aggregation benefits at the Network layer and MAC layer by modeling the energy consumption for some energy-efficient routing protocols and MAC protocols. Besides, we define two parameters, the aggregation ratio and the packet size coefficient to evaluate the efficiency of an aggregation method, and to discuss the trade-off. Additionally, we investigate the differences between time series and compressive sensing, which are representative state-of-the-art solutions for forecasting aggregation and compressing aggregation respectively.

6.2.6. Routing in delay-tolerant networks.

Delay-Tolerant Networks (DTN) model systems that are characterized by intermittent connectivity and frequent partitioning. Routing in DTNs has drawn much research effort recently. Since very different kinds of networks fall in the DTN category, many routing approaches have been proposed. In particular, the routing layer in some DTNs has information about the schedules of contacts between nodes and about data traffic demand. Such systems can benefit from a previously proposed routing algorithm based on linear programming that minimizes the average message delay. This algorithm, however, is known to have performance issues that limit its applicability to very simple scenarios. In [9], we propose an alternative linear programming approach for routing in Delay-Tolerant Networks. We show that our formulation is equivalent to that presented in a seminal work in this area, but it contains fewer LP constraints and has a structure suitable to the application of Column Generation (CG). Simulation shows that our CG implementation arrives at an optimal solution up to three orders of magnitude faster than the original linear program in the considered DTN examples.

6.2.7. Performance evaluation of vehicular communications.

Wireless vehicular networks face different problems and challenges, especially in a dense urban environment. In [23], we first characterize the different types of loss in vehicular networks: radio propagation problems, expired security messages, collision with one hop neighbor and collisions with hidden terminals. In a second step, we give the architecture of the wireless vehicular network and describe the Medium Access Control (MAC) quality of service mechanisms proposed by vehicular environment standards that aim at meeting the road drivers' expectation and increasing road safety. To complete this image, in [24], we provide a literature survey that covers the solutions proposed in order to enable critical dissemination of urgent messages and surpass the challenging vehicular dynamic topology. More particularly, we detail the following techniques: beaconing frequency reduction, transmit rate control, power control, adaptation of the contention window and adaptation of the carrier sense threshold.

6.2.8. Secure node localization in mobile ad-hoc networks.

A growing number of ad hoc networking protocols and location-aware services require that mobile nodes learn the position of their neighbors. However, such a process can be easily abused or disrupted by adversarial nodes. In absence of a priori trusted nodes, the discovery and verification of neighbor positions presents challenges that have been scarcely investigated in the literature. In [6], we address this open issue by proposing a fully distributed cooperative solution that is robust against independent and colluding adversaries, and can be impaired only by an overwhelming presence of adversaries. Results show that our protocol can thwart more than 99% of the attacks under the best possible conditions for the adversaries, with minimal false positive rates.

In a vehicular context, knowledge of the location of vehicles and tracking of the routes they follow are a requirement for a number of applications. However, public disclosure of the identity and position of drivers jeopardizes user privacy, and securing the tracking through asymmetric cryptography may have an exceedingly high computational cost. In [11], we address all of the issues above by introducing A-VIP, a lightweight privacy-preserving framework for tracking of vehicles. A-VIP leverages anonymous position beacons from vehicles, and the cooperation of nearby cars collecting and reporting the beacons they hear. Such information allows an authority to verify the locations announced by vehicles, or to infer the actual ones if needed. We assess the effectiveness of A-VIP through testbed implementation results.

6.3. Cellular network solutions

Participants: Marco Fiore, Anis Ouni, Hervé Rivano, Razvan Stanica, Fabrice Valois

6.3.1. Optimizing capacity and energy consumption in wireless mesh networks.

Wireless mesh networks (WMN) are a promising solution to support high data rate and increase the capacity provided to users, e.g. for meeting the requirements of mobile multimedia applications. However, the rapid growth of traffic load generated by the terminals is accompanied by an unsustainable increase of energy consumption, which becomes a hot societal and economical challenges. This thesis relates to the problem of the optimization of network capacity and energy consumption of wireless mesh networks. The network capacity is defined as the maximum achievable total traffic in the network per unit time.

The thesis of Anis Ouni [3] addresses this issue and is divided into four main parts. First, we address the problem of improvement of the capacity of 802.11 wireless mesh networks. We highlight some insensible properties and deterministic factors of the capacity, while it is directly related to a bottleneck problem. Then, we propose a joint TDMA/CSMA scheduling strategy for solving the bottleneck issue in the network.

Second, we focus on broadband wireless mesh networks based on time-frequency resource management. In order to get theoretical bounds on the network performances, we formulate optimization models based on linear programming and column generation algorithm. These models lead to compute an optimal offline configuration which maximizes the network capacity with low energy consumption. A realistic SINR model of the physical layer allows the nodes to perform continuous power control and use a discrete set of data rates.

Third, we use the optimization models to provide practical engineering insights on WMN. We briefly study the tradeoff between network capacity and energy consumption using a realistic physical layer and SINR interference model [27]. In particular, we show that power control and multi-rate functionalities allow to reach optimal throughput with lower energy consumption using a mix of single hop and multi- hop routes.

Finally, we focus on capacity and energy optimization for heterogeneous cellular networks. We develop optimization tools to calculate an optimal configuration of the network that maximizes the network capacity with low energy consumption. We then propose a heuristic algorithm that calculates a scheduling and partial sleeping of base stations in two different strategies, called LAFS and MAFS.

6.3.2. Sleep protocols for heterogeneous LTE networks.

The tremendous increase of the traffic demand in cellular networks imposes a massive densification of the traditional cellular infrastructure. The network architecture becomes heterogeneous, in particular 4G networks where LTE micro-eNodeBs are deployed to strengthen the coverage of macro-eNodeBs. This densification yields major issues related to the energy consumption of the infrastructure. Indeed, there is fixed and significant amount of energy required to run each additional node, whatever the traffic load of the network. Mitigating this fixed energy consumption is therefore a major challenge from a societal and economical viewpoint. Extensive researches about energy-saving highlight that to save energy the better strategy is to switch off the radio part of nodes. This is the heart of wireless sensor networks energy-saving strategies, even though the objective for WSN is to maximize the battery life of each individual nodes. In [18], we develop a parallel between the principles of WSN protocols and the requirements of cellular infrastructures. We then propose a distributed and localized algorithm to dynamically switch off and on the micro-eNodeBs of an LTE heterogeneous network following the traffic demand evolution in time and analyze it in terms of energy savings. We show that one can expect energy savings of approximately 12% when implementing sleep modes whereas the energy cost for sending the traffic decreases by 24%.

6.3.3. Content downloading through a vehicular network.

The focus of the work we present in [7] is twofold: information dissemination from infrastructure nodes deployed along the roads, the so-called Road-Side Units (RSUs), to passing-by vehicles, and content downloading by vehicular users through nearby RSUs. In particular, in order to ensure good performance for both content dissemination and downloading, the presented study addresses the problem of RSU deployment and reviews previous work that has dealt with such an issue. The RSU deployment problem is then formulated as an optimization problem, where the number of vehicles that come in contact with any RSU is maximized, possibly considering a minimum contact time to be guaranteed. Since such optimization problems turn out to be NP-hard, heuristics are proposed to efficiently approximate the optimal solution. The RSU deployment obtained through such heuristics is then used to investigate the performance of content dissemination and downloading through ns2 simulations. Simulation tests are carried out under various real-world vehicular environments, including a realistic mobility model, and considering that the IEEE 802.11p standard is used at the physical and medium access control layers. The performance obtained in realistic conditions is discussed with respect to the results obtained under the same RSU deployment, but in ideal conditions and protocol message exchange. Based on the obtained results, some useful hints on the network system design are provided.

6.3.4. Offloading Floating Car Data.

Floating Car Data (FCD) is currently collected by moving vehicles and uploaded to Internet-based processing centers through the cellular access infrastructure. As FCD is foreseen to rapidly become a pervasive technology, the present network paradigm risks not to scale well in the future, when a vast majority of automobiles will be constantly sensing their operation as well as the external environment and transmitting such information towards the Internet. In order to relieve the cellular network from the additional load that widespread FCD can induce, we study [16] a local gathering and fusion paradigm, based on vehicle-to-vehicle (V2V) communication. We show how this approach can lead to significant gain, especially when and where the cellular network is stressed the most. Moreover, we propose several distributed schemes to FCD offloading based on the principle above that, despite their simplicity, are extremely efficient and can reduce the FCD capacity demand at the access network by up to 95%.

6.3.5. Mobile malware propagation in vehicular networks.

The large-scale adoption of vehicle-to-vehicle (V2V) communication technologies risks to significantly widen the attack surface available to mobile malware targeting critical automobile operations. Given that outbreaks of vehicular computer worms self-propagating through V2V links could pose a significant threat to road traffic safety, it is important to understand the dynamics of such epidemics and to prepare adequate countermeasures. In [17], we perform a comprehensive characterization of the infection process of variously behaving vehicular worms on a road traffic scenario of unprecedented scale and heterogeneity. We then propose a simple yet effective data-driven model of the worm epidemics, and we show how it can be leveraged for smart patching infected vehicles through the cellular network in presence of a vehicular worm outbreak.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

- A new bilateral collaboration between Orange Labs and Inria UrbaNet started on July 2013. For 3 years, we will investigate how to adapt service level agreements (SLA) concept to wireless sensor networks. The goal is to share a WSN infrastructure to several clients and applications. This approach is quite new because related work mainly view WSN as a data-centric architecture dedicated for only one application. We extend this limitation, and during this work, we aim at building a telecommunication operator point of view in WSN.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- BQR INSA CROME 12/2013-12/2016
  Participants: Fabrice Valois
  The partners in this project are the CITI DynaMid team and LIRIS. The project studies the coordination of a fleet of mobile robots for the multi-view analysis of complex scenes.

- BQR INSA ARBRE 12/2011-12/2013
  Participants: Hervé Rivano, Fabrice Valois
  The partners in this project are the LIRIS (database), EVS-ITUS (social science) and CETHIL (energetic models for buildings) . The project studies wireless sensor networks deployments from different perspectives. An objective is to provide enough data to calibrate energetic models for buildings with human activity. Another is to study the behavior of people working in monitored zones, in particular with respect to the way data are accessible, represented and navigated. Last is to obtain link quality statistics from a practical deployment with real traffic.
- Labex IMU Priva'Mov 10/2013-10/2016
  Participants: Djamel Benferhat, Razvan Stanica, Hervé Rivano
  The partners in this project are DRIM LIRIS, Inria Privatics, INSA EVS, and LET ENTPE. The aim of this project is to develop and deploy a crowdsensing platform to collect mobility traces from a sample of real users equipped with android devices, while carrying research on privacy preservation issues. Our contribution consists on developing the platform and using the collected data to analyze cellular network offloading strategies.
- ARC 7 animation action "Smart Cities Days" 12/2013
  UrbaNet organized the Smart Cities Days are on the 17th and 18th of December 2013 - http://www.citi-lab.fr/seminar/journees-reseaux-et-smart-cities-17-et-18-decembre-2013/.

8.2. National Initiatives

8.2.1. ANR

- ANR Verso ECOScells 10/2009-12/2012
  Participants: Anis Ouni, Hervé Rivano, Fabrice Valois
  The objective of ECOScells is to study energy efficient microcells networks. Hervé Rivano is leader for Inria side and of the work package focusing on energy efficient wireless backhauling.
- ANR ARESA2 03/2010-08/2013.
  Participants: Alexandre Mouradian, Isabelle Augé-Blum, Fabrice Valois
  The partners in the ANR ARESA2 project are: Orange Labs, Coronis, Inria, LIG, Télécom Bretagne, VERIMAG. Our contributions focus on: resiliency of routing protocols in WSN; how to exploit the heterogeneity in wireless multi-hop network; real-time and QoS support in routing protocols for WSN. This project will end in August 2013. Alexandre Mouradian (Ph.D student) is funded by ARESA2.
- ANR ABCD 10/2013-04/2017.
  Participants: Diala Naboulsi, Marco Fiore, Razvan Stanica
  The partners in the ANR ABCD project are: Orange Labs, Ucopia, Inria UrbaNet, UPMC LIP6 PHARE, Telecom ParisTech. The objective of ABCD is to characterize large-scale user mobility and content consumption in urban areas via mobile data mining, so as to achieve efficient deployment and management of cloud resources via virtual machines. Our contribution in the project consists on the characterization of human mobility and service consumption at a city scale, and the design of appropriate resource allocation techniques at the cellular network level.
- ANR IDEFIX 10/2013-04/2017.
  Participants: Soukaina Cherkaoui, Hervé Rivano, Fabrice Valois
  The partners in the ANR IDEFIX project are: Orange Labs, Alcatel Lucent - Bell Labs, Telecom Paris Tech, Inria UrbaNet, Socrate and Dyogene.

8.2.2. Pôle ResCom

- Ongoing participation (since 2006)
  Communication networks, working groups of GDR ASR, CNRS (http://rescom.inrialpes.fr). Hervé Rivano is member of the scientific committee of ResCom.
  UrbaNet organized the ResCom non-thematic days 18-19th of december 2013 - http://www.citi-lab.fr/seminar/journees-scientifiques-rescom/.

8.2.3. Common Laboratory Inria/Alcatel-Lucent Bell Labs

- ADR Green
  UrbaNet is part of the ADR Green of the common laboratory Inria/Alcatel-Lucent Bell Labs. This ADR provides the PhD grant of Soukaina Cherkaoui on the adaptation of wireless sensor network control protocols for optimizing the energy consumption of heterogeneous cellular LTE networks.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Declared Inria International Partners

- **CNR - IEIIT (Italy)**. The informal cooperation with CNR - IEIIT, consisting on joint publications on mobile crowdsensing and mobile data mining, evolved this year into a strong partnership, following Dr. Marco Fiore's departure from INSA Lyon to CNR - IEIIT. Dr. Fiore remains an external collaborator of the Inria UrbaNet team, actively involved in several research projects.

8.3.1.2. Informal International Partners

- **Politecnico di Torino (Italy)**. Multiple publications co-authored with members of the Telecommunication Networks Group.
- **Universidade Federal de Minas Gerais (Brazil)**. Collaboration with Pedro Vaz de Melo and Antonio F. Loureiro on social mobility analysis.
- **Universitat Politecnica de Catalunya (Spain))**. Cooperation and joint publications on mobile malware propagation.
- **University of Waterloo (Ontario, Canada)**. Cooperation and joint publications on the optimization of wireless mesh networks.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- **Artur Ziviani**, LNCC, Brazil, 11/2013 (one week)

8.4.1.1. Internships

Sarah Allali

Subject: Network management of Floating Car Data

Date: from Feb 2013 until Jun 2013

Institution: University Claude Bernard Lyon 1 (France)

Silvia Ancona

Subject: Offloading Floating Car Data

Date: from Oct 2013 until Feb 2014

Institution: Politecnico di Bari (Italy)

Egert-Priit Arus

Subject: Integrating Electric Vehicles with Smart Grids
Date: from Oct 2012 until Jan 2013
Institution: Tallinn University of Technology (Estonia)

Julien Delaborde
Subject: From theory to experimentation: the missing link in protocols conception in WSN
Date: from Feb 2013 until Sep 2013
Institution: University Claude Bernard Lyon 1 (France)

Ibrahima Fall
Subject: Topologies des re´seaux urbains: Proprie´te´s et Impacts
Date: from Feb 2013 until Jun 2013
Institution: University Claude Bernard Lyon 1 (France)

Mohammad Irfan Khan
Subject: Information Dissemination in Vehicular Networks
Date: from Mar 2013 until Oct 2013
Institution: INSA Lyon (France)

Yufei Li
Subject: Evaluating energy saving protocols for LTE micro-cell infrastructure
Date: from Sep 2013 until Dec 2013
Institution: INSA Lyon (France)

Sorin Serban Marc
Subject: Signal propagation for vehicular communications in a large-scale urban scenario
Date: from Feb 2013 until Jun 2013
Institution: University of Oradea (Romania)

Soukaina Merzouk
Subject: Radio Propagation in an Urban Vehicular Environment
Date: from Jul 2013 until Aug 2013
Institution: EMSI Rabat (Morocco)

Keijiro Nakagawa
Subject: Multicommodity flow in delay tolerant networks
Date: from Sep 2012 until Jan 2013
Institution: Tokyo University (Japan)

Xuan Linh Nguyen
Subject: Agrégation de données temps-réel et fiable dans les réseaux de capteurs sans fil
Date: from Feb 2013 until Sep 2013
Institution: INSA Lyon (France)

Duc Khoa Pham

Subject: Characterization of Congestion Problems in Vehicular Networks

Date: from Oct 2013 until Dec 2013

Institution: INSA Lyon (France)

Stine Sondergaard

Subject: Vehicular Mobility Simulation

Date: from Oct 2013 until Jan 2014

Institution: Technical University of Denmark (Denmark)

Hamadoun Tall

Subject: Optimizing energy consumption of RPL

Date: from Apr 2013 until Oct 2013

Institution: Institution de la Francophonie pour l'Informatique (Vietnam)

Ionut Radu Toma

Subject: Signal propagation for vehicular communications in a large-scale urban scenario

Date: from Feb 2013 until Jun 2013

Institution: University of Oradea (Romania)

8.4.2. Visits to International Teams

- **Diala Naboulsi** was a visiting scholar within the Telecommunication Networks Group at Politecnico di Torino (Italy), between Sep 2013 and Jan 2014, under the CMIRA Explora'Doc programme.
- **Hervé Rivano** was a visiting researcher at University of Waterloo (Ontario, Canada), in September 2013.

9. Dissemination

9.1. Scientific Animation

- Walid Bechkit is/was reviewer for IEEE Transaction on Wireless Communications, Ad-Hoc Networks Journal, Journal of Network and Computer Applications, IEEE ICC 2013, IEEE WCN 2014.
- Walid Bechkit is in charge of seminar organization at the CITI laboratory.
- Khaled Boussetta is/was TPC member for a number of international conferences, including IEEE ICC, IEEE GlobeCom, IEEE MASS, IEEE VTC (fall/Spring), Wireless Days, Med-Hoc-Net, ICCVE, GIIS.
- Khaled Boussetta organized two technical sessions at University of Paris 13, one on Optimization for Networks in July 2013 and a second on Cloud Networks in October 2013.
- Marco Fiore was co-chair at IFIP/IEEE Wireless Days'13 for the Track Wireless Models and Simulation.
- Marco Fiore is/was TPC member for a number of international conferences, including IEEE SECON 2013/2014, IEEE WoWMoM 2013/2014, IEEE Globecom 2014, IEEE ICC 2014, IEEE VTC-Fall 2013.
- Hervé Rivano is TPC member of several international conferences, including IEEE IPDPS 2014 and IEEE ICC 2014.

- Hervé Rivano is elected member of the CITI laboratory council.
- Razvan Stanica was Local co-chair of IEEE WiMob 2013.
- Razvan Stanica was Session chair for a Networking track session at IEEE WiMob 2013.
- Razvan Stanica is/was TPC member for a number of international conferences, including IEEE ICC 2014, IEEE PIMRC 2013, IEEE VTC Spring/Fall 2013.
- Razvan Stanica is/was reviewer for IEEE Transaction on Mobile Computing, Ad-Hoc Networks Journal, IEEE Communications Magazine, Springer Wireless Networks, Vehicular Communications Journal.
- Fabrice Valois was General co-chair of IEEE WiMob 2013.
- Fabrice Valois is/was TPC member for several international conferences such as: IEEE AINA, IEEE Globecom, IEEE ICC, IEEE VTC, IEEE WCNC, IARIA SensorComm, IEEE WiMob.
- Fabrice Valois is in charge of the foreign affairs of the CITI laboratory.
- Fabrice Valois is correspondent member of the CITI laboratory for the Labex IMU.
- Fabrice Valois is elected member of the CITI laboratory council.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Isabelle Augé-Blum, Operating Systems, 70h, L3, Telecom. Dpt. INSA Lyon, France.

Licence : Walid Bechkit, IP Networks, 10h, L3, Telecom. Dpt. INSA Lyon, France.

Licence : Razvan Stanica, Network Programming, 90h, L3, Telecom. Dpt. INSA Lyon, France.

Licence : Razvan Stanica, Advanced Wireless Networks, 20h, L3, IST / Telecom. Dpt. INSA Lyon, France (lectures given in english).

Licence : Fabrice Valois, IP Networks, 100h, L3, Telecom. Dpt. INSA Lyon, France.

Licence : Fabrice Valois, IP Networks, 20h, L3, IST / Telecom. Dpt. INSA Lyon, France (lectures given in english).

Master : Isabelle Augé-Blum, Innovation project, 30h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Isabelle Augé-Blum, Bibliographical study, 30h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Isabelle Augé-Blum, Real-Time Networks, 25h, M2, Telecom. Dpt. INSA Lyon, France.

Master : Isabelle Augé-Blum, Networks of the Future, 10h, M2, University of Lyon.

Master : Walid Bechkit, Network architectures, protocols and services, 12h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Marco Fiore, Performance evaluation of telecom networks, 60h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Razvan Stanica, Wireless local area networks, 8h, M2, University of Lyon.

Master : Razvan Stanica, Mobile Networks, 10h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Fabrice Valois, Cellular Networks, 40h, M1, Telecom. Dpt. INSA Lyon, France.

Master : Fabrice Valois, Wireless Multihop networks, 10h, M2, University of Lyon.

Master : Fabrice Valois, Wireless Sensor Networks, 6h, M2, University of Grenoble.

Isabelle Augé-Blum is in charge of the foreign affairs of the Telecommunications department at INSA Lyon, coordinating all incoming and outgoing student exchange programs.

Isabelle Augé-Blum is an elected member of the Telecommunications Department Council at INSA Lyon.

Razvan Stanica is responsible for the administrative part related to all Master projects prepared by INSA Lyon Telecommunications department students.

Fabrice Valois is responsible of the networking teaching team in the Telecommunications department at INSA Lyon, coordinating all the courses in the networking domain.

Since 2006, Fabrice Valois is the head of an international teaching program focused on Internet of Things, established between INSA Lyon and Shanghai Jiao Tong University.

Fabrice Valois is an elected member of the Telecommunications Department Council at INSA Lyon.

9.2.2. Supervision

PhD : Ochirkhand Erdene-Ochir, Résilience et application aux protocoles de routage dans les réseaux de capteurs, INSA Lyon, 07/2013, Advisors: Fabrice Valois, Marine Minier (Inria Privatics).

PhD : Alexandre Mouradian, Proposition et vérification formelle de protocoles temps-réel pour les réseaux de capteurs sans fil, INSA Lyon, 11/2013, Advisors: Fabrice Valois, Isabelle Augé-Blum.

PhD : Anis Ouni, Optimisation de la capacité et de la consommation énergétique dans les réseaux maillés sans fil,INSA Lyon, 12/2013, Advisors: Fabrice Valois, Hervé Rivano.

PhD : Sandesh Uppoor, Understanding and exploiting mobility in wireless networks, INSA Lyon, 11/2013, Advisors: Marco Fiore, Fabrice Valois.

PhD in progress : Soukaina Cherkaoui, Energy-saving strategies for backhaul networks, since 11/2013. Advisors: Hervé Rivano, Fabrice Valois.

PhD in progress : Jin Cui, Aggregation: From data dynamics to network dynamics, since 11/2012. Advisor: Fabrice Valois.

PhD in progress : Rodrigue Domga Komguem, Autonomous WSN architectures for road traffic applications, since 11/2012. Advisors: Fabrice Valois, Razvan Stanica, Maurice Tchuente (Univ. Yaounde´, Cameroun).

PhD in progress : Guillaume Gaillard, SLA pour réseaux de capteurs multi-services, since 12/2012. Advisor: Fabrice Valois.

PhD in progress : Quentin Lampin, QoS constraints and time constraints in WSN, since 10/2009. Advisors: Isabelle Auge´-Blum, Fabrice Valois.

PhD in progress : Trista Lin, Urban mobility measurement and citizen-oriented services cartography, since10/2012. Advisors: Frédéric Le Mouel (CITI DynaMid), Hervé Rivano, Fabrice Valois.

PhD in progress : Diala Naboulsi, Human mobility - an urban networking perspective, INSA Lyon, since 10/2012. Advisors: Razvan Stanica, Marco Fiore, Fabrice Valois.

9.2.3. Juries

- Khaled Boussetta was external examiner of the following Ph.D. defense:
  - Lionel Bertaux, Architecture Réseau pour Véhicule de transport en commun communiquant, LAAS, Université Toulouse 3 Paul Sabatier, 10/2013.
- Isabelle Augé-Blum was external examiner of the following Ph.D. defense:
  - Muhammad Adnan, Exact Worst-Case Communication Delay Analysis of AFDX Network, INP Toulouse, 11/2013.
- Fabrice Valois was external examiner of the following HDR defenses:
  - Emmanuel Chaput, Architecture et gestion de ressources dans les réseaux satellite et véhiculaires, IRIT, ENSEEIHT, INP Toulouse, 11/2013.
  - Tahiry Razafindralambo, Mouvements Autonomes : vers la Créativité dans les Réseaux sans fil, Université de Lille 1, 12/2013.
  - Rami Langar, Urban Wireless Networks : Mobility, Routing, and Resource Management Concerns, LIP6, UPMC, 12/2013.
- Fabrice Valois was external reviewer of the following PhD defenses:

  - Abbas Antoun Hatoum, Gestion des Ressources et d'Interférences dans les Réseaux FemtoCell OFDMA, LIP6, UPMC, 03/2013.
  - Julien Beaudaux, Auto-configuration et auto-adaptation de réseaux de capteurs sans-fil dans le contexte de la télémédecine, I-CUBE, Université de Strasbourg, 09/2013.
  - Jean-François Malbranque, IP sur UHF, Université de Toulon, 12/2013.
- Fabrice Valois was external examiner of the following PhD defenses:
  - Cédric Chauvenet, Protocoles de support IPv6 pour réseaux de capteurs sur courant porteur en ligne, LIG, Université de Grenoble, 10/2013.
- Fabrice Valois was president of a CoS 27 for a MCF position at INSA Lyon.
- Fabrice Valois was member of a CoS 27 for a Full Professor position at INSA Lyon.

9.3. Popularization

- Khaled Boussetta gave a keynote talk entitled "Cloud gaming: state of the art and open challenges", organized by the International Cloud Computing School (ICCS 2013), Hammamet Tunisia, in Dec 2013.
- Fabrice Valois gave an 8h course on ISN (Informatique et Sciences du Numérique). These lectures are made for the Rectorat of Lyon, the public is high school teachers.
- Trista Lin participated to *Fête de la science 2013*, between Oct 8-11. She was responsible for the animation "Best Route - Intelligent Mobility", at La Mache Highschool.
- Hervé Rivano gave a keynote talk entitled "Column Generation for optimization of wireless mesh networks", in the Optimization days of University of Paris XIII.

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[5] M. FIORE, C. CASETTI, C.-F. CHIASSERINI, D. BORSETTI. *Persistent Localized Broadcasting in VANETs*, in "IEEE Journal on Selected Areas in Communications", September 2013, vol. 31, n^{o} 9, pp. 480-490, http://hal.inria.fr/hal-00741117

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