Activity Report 2019

Team EASE

Enabling Affordable Smarter Environment

Joint team with Inria Rennes – Bretagne Atlantique

D2 – Networks, Telecommunications and Services

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Project-Team EASE

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A2.5.4. - Software Maintenance & Evolution
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A2.6.1. - Operating systems
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2. Overall Objectives

2.1. Presentation

The technologies necessary for the development of pervasive applications are now widely available and accessible for many uses: short/long-range and low energy communications, a broad variety of visible (smart objects) or invisible (sensors and actuators) objects, as well as the democratization of the Internet of Things (IoT). Large areas of our living spaces are now instrumented. The concept of Smart Spaces is about to emerge, based upon both massive and apposite interactions between individuals and their everyday working and living environments: residential housing, public buildings, transportation, etc. The possibilities of new applications are boundless. Many scenarios have been studied in laboratories for many years and, today, a real ability to adapt the environment to the behaviors and needs of users can be demonstrated. However mainstream pervasive applications are barely existent, at the notable exception of the ubiquitous GPS-based navigators. The opportunity of using vast amount of data collected from the physical environments for **several application domains** is still largely untapped. The applications that interact with users and act according to their environment with a large autonomy are still very specialized. They can only be used in the environment they had especially been developed for (for example "classical" home automation tasks: comfort, entertainment, surveillance). They are difficult to adapt to increasingly complex situations, even though the environments in which they evolve are more open, or change over time (new sensors added, failures, mobility etc.).

Developing applications and services that are ready to deploy and evolve in different environments should involve significant cost reduction. Unfortunately, designing, testing and ensuring the maintenance as well as the evolution of a pervasive application remain very complex. In our view, the lack of resources by which properties of the real environment are made available to application developers is a major concern. Building a pervasive application involves implementing one or more logical control loops which include four stages (see figure 1-a): (1) data collection in the real environment, (2) the (re)construction of information that is meaningful for the application and (3) for decision making, and finally, (4) action within the environment. While many decision-algorithms have been proposed, the **collection** and **construction** of a reliable and relevant perception of the environment and, in return, **action** mechanisms within the environment still pose major challenges that the TACOMA/EASE project is prepared to deal with.

Most current solutions are based on a massive collection of raw data from the environment, stored on remote servers. Figure 1-a illustrates this type of approach. Exposure of raw sensor values to the decision-making process does not allow to build relevant contexts that a pervasive application actually needs in order to shrewdly act/react to changes in the environment. So, the following is left up to the developer:

- To characterize more finely raw data beyond its simple value, for example, the acquisition date, the nature of network links crossed to access the sensor, the durability and accuracy of value reading, etc.
- To exploit this raw data to calculate a relevant abstraction for the application, such as, whether the room is occupied, or whether two objects are in the same physical vicinity.
- To modify the environment when possible.

Traditional software architectures isolate the developer from the real environment that he has to depict according to complex, heavy and expensive processes. However, objects and infrastructure integrated into user environments could provide a more suitable support to pervasive applications: description of the actual system's state can be richer, more accurate, and, meanwhile, easier to handle; the applications' structure can be distributed by being built directly into the environment, facilitating scalability and resilience by the processing autonomy; finally, moving processing closer to the edge of the network avoids major problems of data sovereignty and privacy encountered in infrastructures very dependent on the cloud. We strongly believe in the advantages of specific approaches to the fields of **edge computing** and **fog computing**, which will reveal themselves with the development of Smart Spaces and an expansive growth of the number of connected objects. Indeed, ensuring the availability and reliability of systems that remain frugal in terms of resources will become in the end a major challenge to be faced in order to allow proximity between processing and end-users. Figure 1-b displays the principle of "using data at the best place for processing". Fine decisions can be made closer to the objects producing and acting on the data, local data characterization and local processing de-emphasize the computing and storage resources of the cloud (which can be used for example to store selected/transformed data for global historical analysis or optimization).

EASE aims at developing a comprehensive set of new **interaction models** and **system architectures** to considerably help pervasive application designers in the development phase with the side effect to ease the life cycle management. We follow two main principles:

- Leveraging local properties and direct interactions between objects, we would be able to enrich and to manage locally data produced in the environment. The application would then be able to build their knowledge about their environment (perception) in order to adjust their behavior (eg. level of automation) to the actual situation.
- Pervasive applications should be able to describe requirements they have on the quality of their environment perception. We would be able to achieve the minimum quality level adapting the diversity of the sources (data fusion/aggregation), the network mechanisms used to collect the data (network/link level) and the production of the raw data (sensors).

3. Research Program

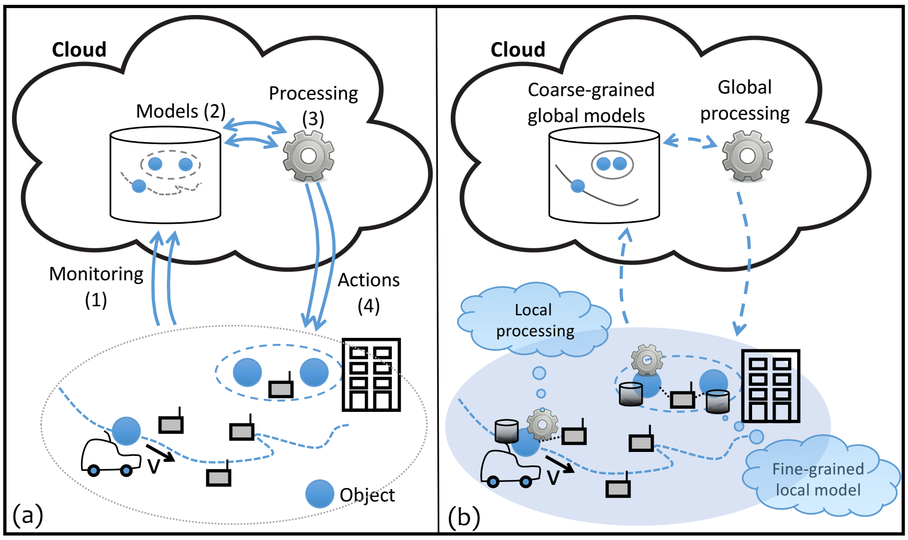

Figure 1. Adaptation processes in pervasive environments

3.1. Collecting pertinent information

In our model, applications adapt their behavior (for instance, the level of automation) to the quality of their perception of the environment. This is important to alleviate the development constraint we usually have on automated systems. We "just" have to be sure a given process will always operate at the right automation level given the precision, the completeness or the confidence it has on its own perception. For instance, a car passing through crossing would choose its speed depending on the confidence it has gained during perception data gathering. When it has not enough information or when it could not trust it, it should reduce the automation level, therefore the speed, to only rely on its own sensors. Such adaptation capability shift requirements from the design and deployment (availability, robustness, accuracy, etc.) to the **assessment of the environment perception** we aim to facilitate in this first research axis.

Data characterization. The quality (freshness, accuracy, confidence, reliability, confidentiality, etc.) of the data are of crucial importance to assess the quality of the perception and therefore to ensure proper behavior. The way data is produced, consolidated, and aggregated while flowing to the consumer has an impact on its quality. Moreover part of these quality attributes requires to gather information at several communication layers from various entities. For this purpose, we want to design **lightweight cross-layer interactions** to collect relevant data. As a "frugality" principle should guide our approach, it is not appropriate to build all attributes we can imagine. It is therefore necessary to identify attributes relevant to the application and to have mechanisms to activate/deactivate at run-time the process to collect them.

Data fusion. Raw data should be directly used only to determine low-level abstraction. Further help in abstracting from low-level details can be provided by **data fusion** mechanisms. A good (re)construction of a meaningful information for the application reduces the complexity of the pervasive applications and helps the developers to concentrate on the application logic rather on the management of raw data. Moreover, the reactivity required in pervasive systems and the aggregation of large amounts of data (and its processing) are antagonists. We study **software services that can be deployed closer to the edge of the network**. The exploration of data fusion technics will be guided by different criteria: relevance of abstractions produced for pervasive applications, anonymization of exploited raw data, processing time, etc.

Assessing the correctness of the behavior. To ease the design of new applications and to align the development of new products with the ever faster standard developments, continuous integration could be used in parallel with continuous conformance and interoperability testing. We already participate in the design of new shared platforms that aims at facilitating this providing remote testing tools. Unfortunately, it is not possible to be sure that all potential peers in the surrounding have a conform behavior. Moreover, upon failure or security breach, a piece of equipment could stop to operate properly and lead to global mis-behavior. We want to propose conceptual tools for **testing at runtime devices in the environment**. The result of such conformance or interoperability tests could be stored safely in the environment by authoritative testing entity. Then application could interact with the device with a higher confidence. The confidence level of a device could be part of the quality attribute of the information it contributed to generate. The same set of tools could be used to identify misbehaving device for maintenance purpose or to trigger further testing.

3.2. Building relevant abstraction for new interactions

The pervasive applications are often designed in an ad hoc manner depending on the targeted application area. Ressources (sensors / actuators, connected objets etc.) are often used in silos which complexify the implementation of rich pervasive computing scenarios. In the second research axis, we want to get away from technical aspects identifying **common and reusable system mechanisms** that could be used in various applications.

Tagging the environment. Information relative to environment could be stored by the application itself, but it could be complex to manage for mobile application since it could cross a large number of places with various features. Moreover the developer has to build its own representation of information especially when he wants to share information with other instances of the same application or with other applications. A promising approach is to store and to maintain this information associated to an object or to a place, in the environment itself. The infrastructure should provide services to application developers: add/retrieve information in the environment, share information and control who can access it, add computed properties to object for further usage. We want to study an **extensible model to describe and augment the environment**. Beyond a simple distributed storage, we have in mind a new kind of interaction between pervasive applications and changing environment and between applications themselves.

Taking advantages of the spatial relationships. To understand the world they have to interact with, pervasive applications often have to (re)built a model of it from the exchange they have with others or from their own observations. A part of the programmer's task consists in building a model of the spatial layout of the objects in the surrounding. The term *layout* can be understood in several ways: the co-location of multiple objects in the same vicinity, the physical arrangement of two objects relative to each other, or even the crossing of an object of a physical area to another, etc. Determining remotely these spatial properties (see figure 1-a) is difficult without exchanging a lot of information. Properties related to the spatial layout are far easier to characterize locally. They could be abstracted from interaction pattern without any complex virtual representation of the environment (see figure 1-b). We want to be able to rely on this type of spatial layout in a pervasive environment. In the prior years, the members of EASE already worked on **models for processing object interactions** in the physical world to automatically trigger processing. This was the case in particular of the spatial programming principle: physical space is treated as a tuple-space in which objects are automatically synchronized according to their spatial arrangement. We want to follow this approach by considering **richer and more expressive programming models.**

3.3. Acting on the environment

The conceptual tools we aim to study must be *frugal*: they use as less as possible resources, while having the possibility to use much more when it is required. Data needed by an application are not made available for "free"; for example, it costs energy to measure a characteristic of the environment, or to transmit it. So this "design frugality" requires **a fine-grained control** on how data is actually collected from the environment. The third research axis aims at designing solutions that give this control to application developers by **acting on the environment**.

Acting on the data collection. We want to be able to identify which information are really needed during the perception elaboration process. If a piece of data is missing to build a given information with the appropriate quality level, the data collection mechanism should find relevant information in the environment or modify the way it aggregates it. These could lead to a modification of the behavior of the network layer and the path the piece of data uses in the aggregation process.

Acting on object interactions. Objects in the environment could adapt their behavior in a way that strongly depends on the object itself and that is difficult to generalize. Beyond the specific behaviors of actuators triggered through specialized or standard interfaces, the production of information required by an application could necessitate an adaptation at the object level (eg. calibration, sampling). The environment should then be able to initiate such adaption transparently to the application, which may not know all objects it passes by.

Adapting object behaviors. The radio communication layers become more flexible and able to adapt the way they use energy to what is really required for a given transmission. We already study how beamforming technics could be used to adapt multicast strategy for video services. We want to show how playing with these new parameters of transmissions (eg. beamforming, power, ...) allows to control spatial relationships objects could have. There is a tradeoff to find between the capacity of the medium, the electromagnetic pollution and the reactivity of the environment. We plan to extend our previous work on interface selection and more generally on what we call **opportunistic networking**.

4. Application Domains

4.1. Pervasive applications in Smart Building

A Smart Building is a living space equipped with information-and-communication-technology (ICT) devices conceived to collaborate in order to anticipate and respond to the needs of the occupants, working to promote their comfort, convenience, security and entertainment while preserving their natural interaction with the environment.

The idea of using the Pervasive Computing paradigm in the Smart Building domain is not new. However, the state-of-the-art solutions only partially adhere to its principles. Often the adopted approach consists in a heavy deployment of sensor nodes, which continuously send a lot of data to a central elaboration unit, in charge of the difficult task of extrapolating meaningful information using complex techniques. This is a *logical approach*. EASE proposed instead the adoption of a *physical approach*, in which the information is spread in the environment, carried by the entities themselves, and the elaboration is directly executed by these entities "inside" the physical space. This allows performing meaningful exchanges of data that will thereafter need a less complicated processing compared to the current solutions. The result is a smart environment that can, in an easier and better way, integrate the context in its functioning and thus seamlessly deliver more useful and effective user services. Our contribution aims at implementing the physical approach in a smarter environment, showing a solution for improving both comfort and energy savings.

4.2. Automation in Smart City

The domain of Smart Cities is still young but it is already a huge market which attracts number of companies and researchers. It is also multi-fold as the words "smart city" gather multiple meanings. Among them one of the main responsibilities of a city, is to organize the transportation of goods and people. In intelligent transportation systems (ITS), ICT technologies have been involved to improve planification and more generally efficiency of journeys within the city. We are interested in the next step where efficiency would be improved locally relying on local interactions between vehicles, infrastructure and people (smartphones).

For the future autonomous vehicle are now in the spotlight, since a lot of works has been done in recent years in automotive industry as well as in academic research centers. Such unmanned vehicles could strongly impact the organisation of the transportation in our cities. However, due to the lack of a definition of what is an "autonomous" vehicle, it is still difficult to see how these vehicles will interact with their environment (eg. road, smart city, houses, grid, etc.). From augmented perception to fully cooperative automated vehicle, the autonomy covers various realities in terms of interaction the vehicle relies on. The extended perception relies on communication between the vehicle and surrounding roadside equipments. That helps the driving system to build and maintain an accurate view of the environment. But at this first stage the vehicle only uses its own perception to make its decisions. At a second stage, it will take advantages of local interaction with other vehicles through car-to-car communications to elaborate a better view of its environment. Such "cooperative autonomy" does not try to reproduce the human behavior anymore, it strongly relies on communication between vehicles and/or with the infrastructure to make decision and to acquire information on the environment. Part of the decision could be centralized (almost everything for an automatic metro) or coordinated by a roadside component. The decision making could even be fully distributed but this put high constraints on the communications. Automated vehicles are just an example of smart city automated processes that will have to share information within the surrounding to make their decisions.

4.3. Pervasive applications in uncontrolled environnements

Some limitations of existing RFID technology become challenging: unlike standard RFID application scenarios, pervasive computing often involves uncontrolled environment for RFID, where tags and reader have to operate in much more difficult situations that those usually encountered or expected for classical RFID systems.

RFID technology is to avoid missing tags when reading multiple objects, as reading reliability is affected by various effects such shadowing or wave power absorption by some materials. The usual applications of RFID operate in a controlled environment in order to reduce the risk of missing tags while scanning objects.

In pervasive computing applications, a controlled reading environment is extremely difficult to achieve, as one of the principle is to enhance existing processes "in situ", unlike the controlled conditions that can be found in industrial processes. Consider for example a logistic application, where RFID tags could be used on items inside a package in order to check for its integrity along the shipping process. Tags would likely be placed randomly on items inside the package, and reading conditions would be variable depending on where the package is checked.

RFID operation in uncontrolled environments is challenging because RFID performance is affected by multiple parameters, in particular:

- Objects materials (on which tags are attached to),
- Materials in the surrounding environment,
- RFID frequency spectrum,
- Antenna nature and placement with respect to the tags.

In controlled environment, the difficulty to read tags can be limited by using the appropriate parameters to maximize the RFID performance for the application. But in many cases, it is needed to read large number of objects of various nature, arranged randomly in a given area or container. **Most pervasive computing applications fall in this context**.

5. New Software and Platforms

5.1. THEGAME

KEYWORD: Contextual service

SCIENTIFIC DESCRIPTION: Context-aware applications have to sense the environment in order to adapt themselves and provide with contextual services. This is the case of Smart Homes equipped with sensors and augmented appliances. However, sensors can be numerous, heterogeneous and unreliable. Thus the data fusion is complex and requires a solid theory to handle those problems. The aim of the data fusion, in our case, is to compute small pieces of context we call context attributes. Those context attributes are diverse and could be for example the presence in a room, the number of people in a room or even that someone may be sleeping in a room. For this purpose, we developed an implementation of the belief functions theory (BFT). THE GAME (THeory of Evidence in a lanGuage Adapted for Many Embedded systems) is made of a set of C-Libraries. It provides the basics of belief functions theory, computations are optimized for an embedded environment (binary representation of sets, conditional compilation and diverse algorithmic optimizations).

THE GAME is published under apache licence (https://github.com/bpietropaoli/THEGAME/). It is maintained and experimented by Aurélien Richez within a sensor network platform developed by TACOMA since June 2013.

FUNCTIONAL DESCRIPTION: THEGAME is a set of software services for detecting different types of situation in a building (presence in a room, activity level, etc.) based on a set of raw data sourced from all sorts of sensors. Written in C or Java, it can be integrated in an embedded computer: tablet, smartphone, box, etc., and can be connected to different sensor networks. It can be used to implement context-aware services: for example, to alert the user if s/he forgets to close a window when leaving the building, or to turn off the heating in an empty room, etc.

- Participants: Aurélien Richez and Bastien Pietropaoli
- Contact: Frédéric Weis
- URL: https://github.com/bpietropaoli/THEGAME/

5.2. Platform Pervasive_RFID

SCIENTIFIC DESCRIPTION

The RFID experiment testbed has been designed and deployed in collaboration with IETR (see Figure 2). This system allows both interactive testing as well as long running experiments of RFID reading protocols. It comprises a software platform allowing fine control over all dynamic aspects influencing RFID readings: movements for target and antenna, RFID reader configuration, and smart antenna configuration (diversity and power control).
KEYWORDS: Composite objects - RFID

- Participants: Paul Couderc and Alexis Girard (Univ. Rennes 1)
- Partner: Univ. Rennes 1 (IETR - lab bringing together researchers in the electronics and telecommunications)
- Contact: Paul Couderc

5.3. ISO/IEC 15118-2 Open source Implementation

SCIENTIFIC DESCRIPTION

The ISO/IEC 15118 standard, named "Road vehicles – Vehicle-to-Grid Communication Interface", defines how an electric vehicle and a charging station should communicate. It enables the Smart Charging of electric vehicles by allowing them to plan their charging sessions. As we want to be able to manage the charge of electric vehicles in our micro Smart Grid systems, we decided to implement the protocol defined by this standard. The goal is also to participate actively in the design of the new version of this protocol. During a charging session the charging station provides the vehicle with the status of the electric power grid. The vehicle is then able to plan its sharing session accordingly. It sends back its charge plan to the charging station, so that the Smart Grid is aware of it. The protocol also provides security and authentication features.

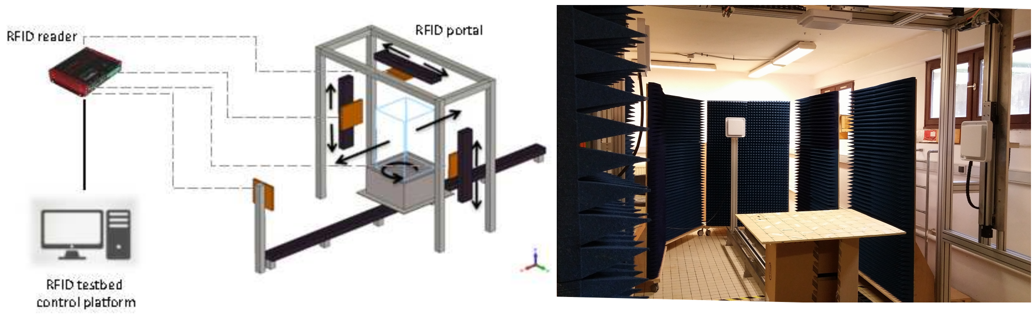

Figure 2. RFID testbed

This software platform was implemented onto small PCs, and was used to control the charge in a small and portable demonstration platform, to demonstrate how it is possible to interconnect this high level decision and communication software with low level components, such as a Battery Management System (BMS), and a battery charger. In 2016, in the context of the Greenfeed project our software has been demonstrated to control the charge of the electric vehicle during the final demonstration of the project. The integration work has been done in collaboration with VeDeCom [1].

KEYWORDS: Smart Grid - Intelligent Transport System

- Partner: IMT Atlantique
- Contact: Jean-Marie Bonnin

6. New Results

6.1. Smart City and ITS

Participants: Indra Ngurah, Christophe Couturier, Rodrigo Silva, Frédéric Weis, Jean-Marie Bonnin [contact].

In the last years, we contributed to the specification of the hybrid (ITS-G5 + Cellular) communication architecture of the French field operation test project SCOOP@F. The proposed solution relies on the MobileIP family of standards and the ISO/ETSI ITS Station architecture we contributed to standardize at IETF and ISO. On this topic our contribution mainly focussed on bringing concepts from the state of the art to real equipments. For the last year of the SCOOP@F part 2 project, we took part to the performance evaluation process by providing a test and validation platform for IP mobility protocols (MobileIP, NEMO) and IPsec cyphering. This platform allows us to identify the performance limits of current implementation of mobility and security protocols. Moreover it spotted implementation incompatibilities between the open source implementations of theses protocols (namely UMIP and StrongSwan) and helped the industrial partners of the project to identify associated risks.

InDiD is the logical follow up of SCOOP@F part 2. This 3.5 years long European project (mid 2019-2023) aims at testing ITS applications on a large scale national deployment of connected vehicles and infrastructure. This version of the project specifically complex use cases (so called day 1.5) and urban application. For the beginning of this project, we proposed several innovative use cases. Our "Backward cartography update" scenario has been selected as a priority candidate for implementation. In line with the collaborative approaches of EASE, we propose to use vehicles' observations to inform other vehicles and/or a cartography server about differences between the digital map and the reality.

[1] http://www.vedecom.fr/

We also want to explore the benefits of new capabilities of upcoming communication technologies to enrich the interactions between vehicle and smartphones or wearable devices. We defined an architecture for both localisation and communication with vulnerable users (workers in road and construction works). Short range communications between dangers (maneuvering construction vehicles) and workers rely on the advertisement feature of Bluetooth Low Energy (BLE). This connectionless communication mode enables for easy direct communication between any node in the neighborhood. It is inspired from the ITS-Station communication standard and we aim to integrate our work into future versions of the standards. Another contribution in this project aims at enhancing the localisation precision in harsh conditions. Recent version of radio communication standards (eg. Bluetooth 5.1 or 802.11ax) now integrate intrinsic real time localisation primitives giving information such as Angle of Arrival (AoA), Angle of Departure (AoD) or distance evaluation based on Time of Flight (ToF) measurements. We started to study how to merge this information with other localisation evidence sources and how to structure a collaborative framework to share it with other objects in the environment. This early works opens the doors to many other works in the future.

The development of innovative applications for smart cities has also been made possible by the rise of Internet of Things and especially the deployment of numerous low energy devices. The collection of the huge amount of data produced by all these piece of hardware become a challenge for the communication networks. In smart cities, the mobility of vehicles can be used to collect data produced by connected objects and to deliver them to several applications which are delay tolerant. The Vehicular Delay Tolerant Networks (VDTN) can be utilized for such services. We designed DC4LED (Data Collection for Low Energy Devices): a hierarchical VDTN routing which takes advantage of the specific mobility patterns of the various type of vehicles. It provides a low-cost delivery service for applications that need to gather data generated from the field. The idea is to propose a simple routing scheme where cars, taxis, and buses route data hierarchically in a store-carry-forward mechanism to any of the available Internet Point-of-Presences in the city. We compare using simulation tools the performance of DC4LED routing with two legacy VDTN routing schemes which represent the extreme ends of VDTN routing spectrum: First-contact and Epidemic routing. It show that DC4LED has much lower network overhead in comparison with the two legacy routing schemes, which is advantageous for its implementation scalability. The DC4LED also maintains comparable data delivery probability and latency to Epidemic routing.

The situational viewing and surveillance in cities is one such category of applications which can benefit from various networking solutions available to transport images or data from installed sensor cameras. We explore how our DC4LED mechanism can be used to for a city-wide image and data collection service. We study the networking performance in terms of increasing image sizes that can be transported with respect to varying vehicular density in city. We focus mainly on two technologies for sensors to vehicles communications: ZigBee and ITS-G5. We show that, surprisingly such very simple mechanism could meet the requirements of multiple services.

6.2. Autonomic Maintenance of Optical Networks

Participant: Jean-Marie Bonnin [contact].

The application of classification techniques based on machine learning approaches to analyze the behavior of network users has interested many researchers in the last years. In a recent work, we have proposed an architecture for optimizing the upstream bandwidth allocation in Passive Optical Network (PON) based on the traffic pattern of each user. Clustering analysis was used in association with an assignment index calculation in order to specify for PON users their upstream data transmission tendency. A dynamic adjustment of Service Level Agreement (SLA) parameters is then performed to maximize the overall customers' satisfaction with the network. In this work, we extend the proposed architecture by adding a prediction module as a complementary to the first classification phase. Grey Model GM(1,1) is used in this context to learn more about the traffic trend of users and improve their assignment. An experimental study is conducted to show the impact of the forecaster and how it can overcome the limits of the initial model.

This work has been done in collaboration with IRISA-OCIF team.

6.3. Location assessment from local observations

Participants: Yoann Maurel, Paul Couderc [contact].

Confidence in location is increasingly important in many applications, in particular for crowd-sensing systems integrating user contributed data/reports, and in augmented reality games. In this context, some users can have an interest in lying about their location, and this assumption has been ignored in several widely used geolocation systems because usually, location is provided by the user's device to enhance the user's experience. Two well known examples of applications vulnerable to location cheating are Pokemon Go and Waze.

Unfortunately, location reporting methods implemented in existing services are weakly protected: it is often possible to lie in simple cases or to emit signals that deceive the more cautious systems. For example, we have experimented simple and successful replay attacks against Google Location using this approach, as shown on Figure 3.

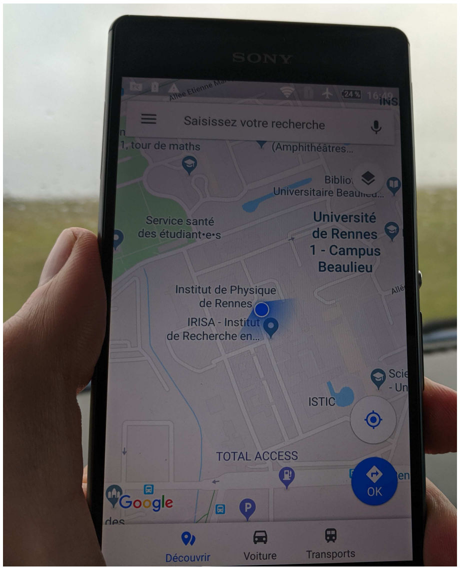

Figure 3. Google map deceived by faked Wi-Fi beacons replayed by an ESP-32

An interesting idea consists in requiring user devices to prove their location, by forcing a secure interaction with a local resource. This idea has been proposed by several works in the literature; unfortunately, this approach requires ad hoc deployment of specific devices in locations that are to be "provable".

We proposed an alternative solution using passive monitoring of Wi-Fi traffic from existing routers. The principle is to collect beacon timestamp observations (from routers) and other attributes to build a knowledge that requires frequent updates to remains valid, and to use statistical test to validate further observations sent by users. Typically, older data collected by a potential attacker will allow him to guess the current state of the older location for a limited timeframe, while the location validation server will get updates allowing him to determine a probability of cheating request.The main strength is its ability to work on existing Wi- Fi infrastructures, without specific hardware. Although it does not offer absolute proof, it makes attacks much more challenging and is simple to implement.

This work was published at CCNC'2019 [1]. We are currently working in broadening this approach, in particular using other attributes of Wi-Fi traffic beside beacon timestamps, and combining the timestamp solution with other type of challenges to propose a diversity of challenges for location validation servers. We are also working on the attack side, which presents interesting perspectives regarding the actual strength of existing services and the potential protection improvements than our approach can provide.

6.4. A methodological framework to promote the use of renewable energy

Participants: Alexandre Rio, Yoann Maurel [contact].

This work is in line with projects aimed at optimizing the use of renewable energies. It is carried out in collaboration with OKWind. This compagny designs and supplies its customers with renewable energy generators such as vertical axis wind turbines and solar trackers. OKWind promotes a micro-grid infrastructure development.

Our application domains are those of agriculture and industry in which it is possible to identify and influence consuming processes. We mainly consider local generation for self-consumption purposes (microgrid) as it limits infrastructure costs, minimizes line losses, reduces the need of the Grid and hopefully reduces the electricity bill.

Renewable energies currently benefit from numerous subsidies to promote their use so as to reduce greenhouse gas emissions. Nevertheless, it seems worth considering the cost-effectiveness of these solutions without these incentives, as they are highly dependent on political will and can be questioned. The reduction in manufacturing costs, particularly in solar energy, suggests that these solutions can eventually compete with traditional sources if they are properly used.

Competitive low-carbon energy is hampered by the stochastic nature of these sources. During peak periods, the electricity produced is competitive, but too often, the scheduled consumption is not aligned with production. In practice, process planning was and is still driven by the electricity price from the grid. On average, the profitability of the installations is therefore not certain. In this context, using battery to shift the load looks appealing but is, as of today, far from being economically viable if not done properly.

Consequently, the achievement of a profitable self-production site is, in practice, a question of trade-off that involves several factors: the scaling of energy sources, the sizing of batteries used, the desired autonomy level, the ecological concerns, and the organization of demand. This trade-off analysis is very challenging: to be carried out effectively and comprehensively, it must be supported by tools that help the stakeholders. While much work has been done in the literature on the impacts of different factors, there are few approaches that offer a comprehensive model.

Our objective is to provide a methodological framework to embrace the diversity of knowledge, of production and consumption tools, of farm activities and of prediction algorithms. This should enable an expert to conduct a trade-off analysis and decide on the best option for each individual site under consideration.

In the first two years of this PhD thesis, we argued that model-driven engineering is suited for the development of such a model and we presented some preliminary implementation. In 2019, we were able to test our approaches in the field and continue to expand the model to account for a wider range of resources. This was published in [5].

6.5. Introducing Data Quality to the Internet of Things

Participants: Jean-Marie Bonnin, Frédéric Weis [contact].

The Internet of Things (IoT) connects various distributed heterogeneous devices. Such Things sense and actuate their physical environment. The IoT pervades more and more into industrial environments forming the so-called Industrial IoT (IIoT). Especially in industrial environments such as smart factories, the quality of data that IoT devices provide is highly relevant. However, current frameworks for managing the IoT and exchanging data do not provide data quality (DQ) metrics. Pervasive applications deployed in the factory need to know how data are "good" for use. However, the DQ requirements differ from a process to another. Actually, specifying/expressing DQ requirements is a subjective task, depending on the specific needs of each targeted application. As an example this could mean how accurate a location of an object that is provided by an IoT system differs from the actual physical position of the object. A Data Quality of 100% could mean that the value represents the actual position. A Data Quality of 0% could mean that the object is not at the reported position. In this example, the value 0% or 100% can be given by a specific software module that is able to filter raw data sent to the IoT system and to deliver the appropriate metric for Dev apps. Building ad hoc solutions for DQ management is perfectly acceptable. But the challenge of writing and deploying applications for the Internet of Things remains often understated. We believe that new approaches are needed, for thinking DQ management in the context of extremely dynamic systems that is the characteristic of the IoT.

In 2019, we introduced DQ to the IoT by (1) representing data quality parameters as metadata to each stored and exchanged IoT data item and (2) providing a toolbox that helps developers to assess the data quality of their processed data using the previously introduced data quality metadata. We followed an inductive approach. Therefore, we set up a pilot to gain first-hand experience with DQ, and to test our developed tools. Our pilot focuses on multi-source data inconsistency. Our setting consists of multiple industrial robots that cowork within a factory. The robots on the line follow a fixed path while the other two robots can freely move. For our implementation we use a data-centric IoT middleware, the Virtual State Layer (VSL). It provides many desired properties such as security and dynamic coupling of services at runtime. Most important it has a strong semantic model for representing data that allows adding new metadata for data quality easily. In our pilot the decrease of the DQ is caused by a low periodicity of location reports. We implemented a DQ service that infers the DQ being located in the service chain. The coordination service queries our DQ enriching service. The DQ enrichment service models the behavior of a robot and infers the resulting DQ depending on the time between the location report and the coordination service's query. Our goal was not only to report the DQ to the consuming service but also to offer tools (microservices) to mitigate from bad DQ. To enable a mitigation from the decreasing DQ, we started the sensors at a random time. This results in the same precision decrease periodicity but in shifted reporting times. The shift enables increasing the DQ by using sensor fusion and data filtering.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

Project: SIMHet

Partner: YoGoKo

Coordinator: JM. Bonnin

Starting: Nov 2015 - Ending: April 2020

Abstract: The SIMHet project is performed in partnership with YoGoKo, a start-up that develops innovative communication solutions for cooperative intelligent transport systems. The SIMHet project aims to develop a decision making mechanism that would be integrated in the ISO/ETSI ITS communication architecture. It will allow mobile devices or mobile routers to choose the best network interface for each embedded application/flow. For example, in a vehicular environment this mechanism could manage global (Internet) and local connections for each on board device/application, in order to ensure that applications and services are always best connected. Aware that "best" concept is context-dependent, such a decision making mechanism should take into account requirements from different actors (e.g., applications, user, network administrators) and contextual information. One of the difficulties is to take advantage of the knowledge the system could have about near future connectivity. In the vehicular context such information about the movement and the availability of network resources is available. If taking into account the future makes the decision making more complex, this could allow a better usage of network resources when they are available. Once current solutions in the market are based on very simple decisions (use WiFi if available and 3G elsewhere), this smart mechanism will give competitive advantage for YoGoKo over its competitors.

7.2. Bilateral Grants with Industry

OKWIND

Coordinator: Y. Maurel

Starting: April 2017 - Ending: April 2020

Abstract: OKWind [2] is a company specialized in local production of renewable energy. This project, with Inria DiverSE and EASE teams, aims at building a system that optimizes the use of different sources of renewable energy, choosing the most suitable source for the current demand and anticipating future needs, so as to favor the consumption of locally produced electricity. The system must be able to model clients' activities. It must also trigger actions (local consumption vs. local storage). The final goal is to use "locally produced" energy in a smarter way and to tend towards a self-consumption optimum. This contract funds Alexandre Rio's PhD grant.

Orange Labs

Coordinator: JM. Bonnin

Starting: Jan 2016 - Ending: Jan 2019

Abstract: The objective of this thesis is to propose a new management architecture for optimizing the upstream bandwidth allocation in PON while acting only on manageable parameters to allow the involvement of self-decision elements into the network. To achieve this, classification techniques based on machine learning approaches are used to analyze the behavior of PON users and specify their upstream data transmission tendency. A dynamic adjustment of some SLA parameters is then performed to maximize the overall customers' satisfaction with the network. This contract funds Nejm Frigui's PhD grant, co-supersized with Tayeb Lemlouma (IRISA OCIF team).

8. Partnerships and Cooperations

8.1. Regional Initiatives

Chantier 3.0

Coordinator: JM. Bonnin

Starting: Jan 2019; Ending : Dec 2021

Partners: Agemos, YoGoKo, IMT Atlantique

Abstract: Co-founded by "Région Bretagne" Chantier 3.0 is a "PME Project" aiming at increasing safety of workers in construction sites and road works. In these scenarios, vehicles represent a danger for the workers. Knowing the position of the vehicles and workers, it is possible to alert workers who are located in a safety perimeter around the vehicles. The project addresses the challenges of 1) precise localisation with low or medium cost wearable devices and 2) of dynamically setting up a reliable communication network in harsh environments mixing indoor and outdoor conditions. The key technologies used to solve theses issues include: fusion of localisation data (GPS, acceleration integration, location anchors, angle of arrival and time of flight of radio signals), opportunistic short range broadcast communications, ITS communication protocols and system integration. EASE brings it expertise in all of theses domains in order to enhance the reliability of the system, to make it affordable and to pave the way for its standardisation.

8.2. National Initiatives

SCOOP@F part 2

Coordinator: JM. Bonnin

Starting: Jan 2016; Ending: Dec 2019

[2] http://www.okwind.fr/

Partners: MEDE, Renault, PSA, IMT Atlantique

Abstract: SCOOP@F is a Cooperative ITS pilot deployment project that intends to connect approximately 3000 vehicles with 2000 kilometers of roads. It consists of 5 specific sites with different types of roads: Ile-de-France, "East Corridor" between Paris and Strasbourg, Brittany, Bordeaux and Isère. SCOOP@F is composed of SCOOP@F Part 1 from 2014 to 2015 and SCOOP@F Part 2 from 2016 to 2019. Its main objective is to improve the safety of road transport and of road operating staff during road works or maintenance. The project includes the validations of Cooperative ITS services in open roads, cross border tests with other EU Member States (Spain, Portugal and Austria) and development of a hybrid communication solution (3G-4G/ITS G5). We are involved in the project to study the security and privacy properties of the hybrid architecture that allow to use non dedicated communication networks (WiFi, 5G) as well as the vehicular dedicated communication technologies (G5). The second phase of SCOOP will end up in 2019. As a partner of the InDiD consortium, we proposed a follow up for this project to the EC for the period 2020-2023.

InDiD

Coordinator: JM. Bonnin

Starting: mid 2019; Ending: Dec 2023

Partners: 20+ French partners including cities (Paris, Grenoble...), road operators, transport operators, academics (incl. IMT Atlantique) and industrials

Abstract: InDiD is one of 13 French projects out of 148 European projects selected by the European Commission within the framework of the last Connecting Europe Facility (CEF) call for proposals. The project benefits from a co-funding rate of 50% on behalf of the European Union. It follows the Smart Cooperative Transport Systems projects SCOOP@F, C-ROADS France and InterCor. The project aims at expanding the coverage of use cases deployed in previous projects (emergency braking, accident, work...) and develop new use cases dealing with urban area, but also use cases of increased perception for autonomous vehicle. In addition, it deals with high definition digital mapping of the infrastructure. Connectivity along with mapping shape the digital infrastructure of tomorrow, an essential addition to the physical infrastructure. InDiD aims at continuing the deployment of Cooperatives Intelligent Transport Systems on new road experimentation sites in order to expand the services coverage offered by the infrastructure. Pilot sites are located on 4 main French geographic areas, on the Mediterranean side, in the south-west area, at the centre and in the north of France.

TAGRI

Coordinator: P. Couderc

Starting: Nov 2019; Ending: Nov 2020

Abstract: Tagri is a 12 months innovation action supported by a CominLabs grant, started on 2019-11-01 and ending on October 2020. It follows up the previous Pervasive_RFID project, a joint Inria - IETR collaboration. Tagri aims at developing an operational UHF RFID solution for agricultural applications where tags are used as a pervasive storage to track important data related to the production. Tagri is using the RFID research facility from Pervasive_RFID project to study the behavior and performance level of UHF RFID in the context of agricultural applications, which is new as the the standard RFID technology used in farming is LF based: historically, LF was selected because it was reliable for bio-tags attached to animal, and the driver application for RFID in smart farming was breeding. A new research engineer, Alexis Girard, has integrated the team in November 2019 on this project.

8.3. International Research Visitors

8.3.1. Informal International Partners

Three years ago we initiated a collaboration with Valerie Gay and Christopher Lawrence (UTS / Australia) on adapting smart spaces for eHealth applications. We continued the collaboration and Jean-Marie Bonnin visited UTS last August. He participated in the definition of research IoT infrastructure for a new maternity clinic dedicated to aboriginal community. The goal was to design an efficient research infrastructure to study how pervasive technologies could be used to adapt the environment to the people. To prepare this visit, Christopher Lawrence came in France and visit the team in March 2019.

8.3.2. Visits of International Scientists

Christopher Lawrence, Associate Professor, University of Technology Sydney, visited the team in March/April 2019.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events: Organisation

9.1.1.1. Member of the Organizing Committees

The E4SE team has been involved from the beginning with the City of Rennes in the design of the inOut event and its experts comitee. inOut is an innovative initiative at the service of new mobility solutions. After holding a first event in March 2018, inOut returned to Rennes in 2019 from 28 to 31 March and will happen again next years. The two-day [IN]door business event, followed by an [OUT]door event open to the general public for the entire weekend, gathers together mobility businesses and users to debate, test, and explore new mobility solutions. At the crossroads of digital technologies and mobilities, inOut seeks to bring out the best these two worlds have to offer by providing a space of discussion and debate, where topics and concepts are unpicked and decoded, and different ideas converge. In addition to the expert-focused [IN] part of the event which targets mobility professionals from all over the world, there is also an [OUT] section that invites the general public to take a weekend to explore and discover this topic of new mobilities. Field tests and experimentations are also conducted as part of inOut to support start-ups, businesses and manufacturers and to encourage them to explore what the future holds.

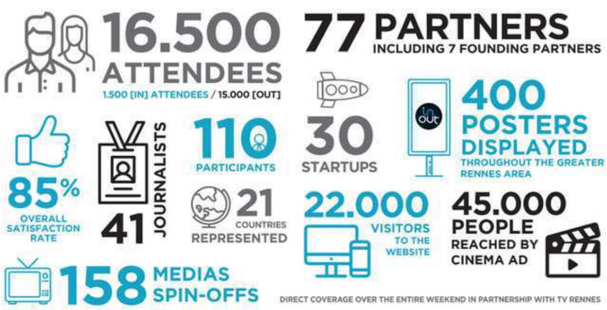

Figure 4. inOut 2019 in figures

inOut is not only an event and we built in with experimentation at the heart of the innovation approach. It has a life beyond the event. It offers an ecosystem of new mobility solutions throughout the year. Experiments, demonstrations, hackathons, and academic challenges get students, researchers, start-ups, and users involved. The call for experiments encourages entrepreneurs and academics to create and test innovations all along the year. An inOut experimentation is conducted in an open-air laboratory: the city of Rennes places its streets and facilities at the disposal of start-ups and companies so that they can test the digital technologies of the city of tomorrow. It aims to provide a response to the need for innovation in communities, to upgrade and develop business sectors, to improve the appeal of the region (companies and universities) for companies and research projects.

9.1.2. Scientific Events: Selection

9.1.2.1. Member of the Conference Program Committees

- PC member of VTC 2019, ICIN 2019, ICON 2019, VEHITS 2020, ICCVE 2019, 3ICT 2019, JM. Bonnin
- PC member of eHPWAS 2019, AdHoc Now 2020, F. Weis

9.1.3. Journal

9.1.3.1. Reviewer - Reviewing Activities

- IEEE Communication Magazine, JM. Bonnin and C. Couturier
- IEEE Access, Wireless Communication and Mobile Computing, The Computer Journal, Transactions on Mobile Computing, Vehicular communications, Journal of sensors, JM. Bonnin
- IEEE Computer, F. Weis

9.1.4. Invited Talks

- Presentation at Security Days @ IRISA, JM Bonnin
- Round table at InOut 2019, JM Bonnin
- Presentation of the EASE activity around Mobile Data collection in Smart City at South West Aboriginal Medical Service, JM Bonnin

9.1.5. Scientific Expertise

- Head of the scientific committee of InOut 2019, JM. Bonnin
- Member of the scientific council of the GIS ITS, JM. Bonnin
- Member of the scientific council the Id4Car cluster, JM. Bonnin
- Scientific advisor of the YoGoKo startup, JM. Bonnin
- Scientific advisor for an INRA team (Unité Expérimentale Ecologie et Ecotoxicologie Aquatiques) on fish tracking issues using LF RFID, P. Couderc
- Co-head of "the pole Digital Society of the MSHB" (Maison des Sciences de l'Homme de Bretagne), JM. Bonnin
- Project evaluation for ANR, Belgium, Id4Car, Région Pays de la Loire, Région Grand Est, JM. Bonnin
- Expert for CSV board of "Pôle Images et Réseaux", projects reviewing and selection, strategic roadmap definition, P. Couderc

9.1.6. Research Administration

- Head of the Networks, Telecommunication and service department at IRISA, JM. Bonnin until Nov 2019
- Member for the IRISA Laboratory Council, JM. Bonnin
- Member of the scientific council of ECAM (Engineering school), JM. Bonnin

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

- L2/L3: network computing (lectures, tutorials, labs), 250 hours, F. Weis, Univ. Rennes 1
- Master 2: Wireless LANs, F. Weis, 30 hours, M2, IMT Atlantique
- Master 2: Pervasive computing and IoT system architectures, 4 hours, P. Couderc, Univ. Rennes 1
- Master 1: Network programming (lectures, tutorial, labs), 78 hours, Y. Maurel, Univ. Rennes 1
- L3/M2: network communications protocol for building automation (lectures, labs), 80 hours, Y. Maurel
- Master 2: Software engineering (lectures, tutorial, labs), 82 hours, Y. Maurel
- Master 2 : Mobility management in the Internet, JM. Bonnin, IMT Atlantique
- Master 2 Smart Mobility : Communications for ITS, JM. Bonnin, IMT Atlantique
- Master 2 IoT: Smart City, JM. Bonnin, ENSI Tunis
- Continuous training: Communications for Autonomous and Cooperative vehicle, Communications for ITS, JM. Bonnin, IMT Atlantique
- Master 1: Network programming (lab and project), 72 hours, C. Couturier, IMT Atlantique
- Master 1: IP networks (lectures, tutorial), 24 hours, C. Couturier, IMT Atlantique
- Master 2: Enterprise Network Design, 12 hours, C. Couturier, IMT Atlantique
- Master 2: Bid to Call for Tender, 12 hours, C. Couturier, IMT Atlantique
- Master 2: Supervision of the Networking and Telecom curriculum of FIP3A, C. Couturier, IMT Atlantique
- Master 2: Tools for cloud computing , 18 hours, C. Couturier, IMT Atlantique

9.2.2. Supervision

PhD in progress: Indra Ngurah, Car-based Data Collection for Low Energy Devices (Car-based DC4LED), May 2016, Jean-Marie Bonnin

PhD in progress: Alexandre Rio, "Modélisation des activités de site consommateur d'énergie", Octobre 2016, Olivier Barais (UR1) and Yoann Maurel

PhD in progress: Rodrigo Silva, "Mécanisme de décision multi-critères pour le placement de flux en environnement hétérogène et changeant", Nov. 2015, Jean-Marie Bonnin

PhD in progress: Nejm Frigui, "Maintenance autonomique du réseau programmable d'accès optiques de très haut débit", Jan. 2016, Jean-Marie Bonnin

9.2.3. Juries

PhD: Mohammad Irfan Khan, "Multi-Service Resource Orchestration for Vehicular Safety Communication", Jean-Marie Bonnin, referee Dec 2019

10. Bibliography

Publications of the year

International Conferences with Proceedings

[1] P. COUDERC, Y. MAUREL. *Location corroboration using passive observations of IEEE 802.11 Access Points*, in "CCNC 2019 - 16th IEEE Consumer Communications & Networking Conference", Las Vegas, United States, IEEE, January 2019, pp. 1-7 [*DOI :* 10.1109/CCNC.2019.8651873], https://hal.inria.fr/hal-01954122

[2] N. I. ER, K. D. SINGH, J.-M. BONNIN. *DC4LED: A Hierarchical VDTN Routing for Data Collection in Smart Cities*, in "CCNC 2019 - 16th IEEE Consumer Communications and Networking Conference", Las Vegas, United States, Proceeding of The 2019 16th IEEE Annual Consumer Communications & Networking Conference (CCNC 2019), IEEE, April 2019, vol. 1, pp. 883-886 [*DOI :* 10.1109/CCNC.2019.8651757], https://hal.archives-ouvertes.fr/hal-01894719

[3] R. SILVA, C. COUTURIER, J.-M. BONNIN, T. ERNST. *A Heuristic Decision Maker Algorithm for Opportunistic Networking in C-ITS*, in "VEHITS 2019 - 5th International Conference on Vehicle Technology and Intelligent Transport Systems", Heraklion, Greece, SCITEPRESS - Science and Technology Publications, May 2019, pp. 578-585 [*DOI :* 10.5220/0007799005780585], https://hal-imt-atlantique.archives-ouvertes.fr/hal-02177505

Conferences without Proceedings

[4] N. I. ER, K. D. SINGH, J.-M. BONNIN. *CityView: A Vehicle Based Image and Data Collection for Smart Cities*, in "WiMob 2019 - 15th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications", Barcelona, Spain, October 2019, pp. 1-7 [*DOI :* 10.1109/WIMOB.2019.8923547], https://hal.archives-ouvertes.fr/hal-02318697

[5] A. RIO, Y. MAUREL, Y. BUGNI, O. BARAIS. *Benefits of Energy Management Systems on local energy efficiency, an agricultural case study*, in "SmartGridComm 2019 - IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids", Beijing, China, IEEE, October 2019, pp. 1-7, https://hal.archives-ouvertes.fr/hal-02315327

Scientific Books (or Scientific Book chapters)

[6] R. SILVA, C. COUTURIER, T. ERNST, J.-M. BONNIN. *Proactive Decision Making for ITS Communication*, in "Global Advancements in Connected and Intelligent Mobility: Emerging Research and Opportunities", IGI Global, July 2019, pp. 197-226 [*DOI :* 10.4018/978-1-5225-9019-4.CH006], https://hal-imt-atlantique.archives-ouvertes.fr/hal-02173428