Activity Report 2016

Team TACOMA

TAngible COMputing Architectures

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Distributed programming and Software engineering

Table of contents

Team TACOMA

Creation of the Team: 2014 January 01

TACOMA ends in December 2016. Since September 2016, the team's composition has evolved including Jean-Marie Bonnin from Telecom Bretagne, and TACOMA addresses new applications domains (mobility, smart cities). The presentation of the research program in this report has been revised to reflect these recent evolutions. This expansion of the team's skill set will be helpful in the future to tackle, at different levels (sensors, network, software), architectural concerns that impairs the deployment of smarter environments.

Keywords:

Computer Science and Digital Science:

1.2. - Networks
1.2.5. - Internet of things
1.2.6. - Sensor networks
1.2.7. - Cyber-physical systems
1.3. - Distributed Systems
1.4. - Ubiquitous Systems
2.3.2. - Cyber-physical systems
2.5. - Software engineering
2.6. - Infrastructure software
2.6.1. - Operating systems
2.6.2. - Middleware
4.8. - Privacy-enhancing technologies
5.11. - Smart spaces
5.11.1. - Human activity analysis and recognition
5.11.2. - Home/building control and interaction

Other Research Topics and Application Domains:

3.1. - Sustainable development
3.1.1. - Resource management
4.4. - Energy delivery
4.4.1. - Smart grids
4.5.2. - Embedded sensors consumption
6.1. - Software industry
6.1.1. - Software engineering
6.1.2. - Software evolution, maintenance
6.2.2. - Radio technology
6.3.3. - Network Management
6.4. - Internet of things
6.6. - Embedded systems
7.2. - Smart travel
7.2.1. - Smart vehicles
7.2.2. - Smart road
8.1. - Smart building/home

8.2. - Connected city
8.5.2. - Crowd sourcing
8.5.3. - Collaborative economy
9.8. - Privacy
9.10. - Ethics

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2. Overall Objectives

2.1. Overall Objectives

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 remains 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 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 oftentimes 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).

TACOMA 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

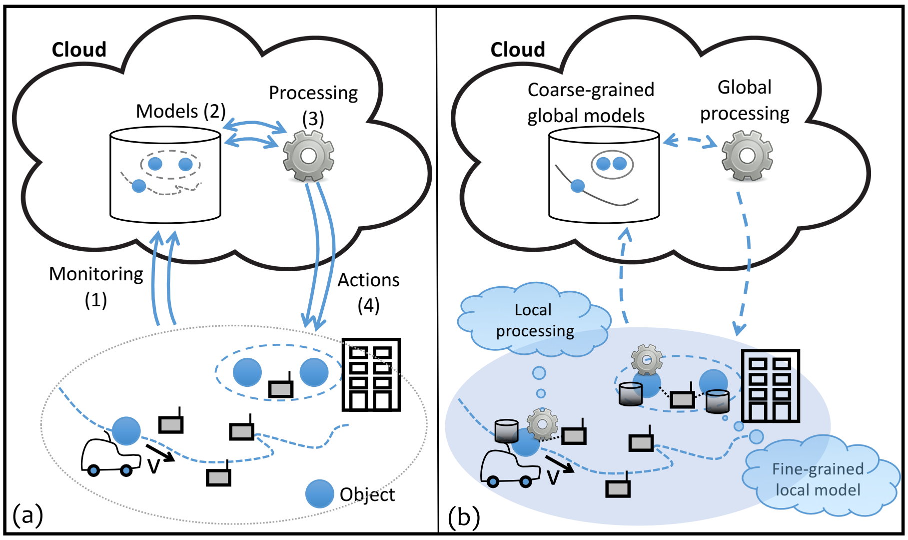


Figure 1. Adaptation processes in pervasive environments

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 system. 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 a cross 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 and temporal 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 TACOMA 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 reality 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 aggregate it. These could lead to a modification of the behavior of the network layer and the path the piece of data use in the aggregation process.

Acting on object interactions. Object in the environment could adapt their behavior in a way that strongly depend 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 expend our previous 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*. TACOMA 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. Metamorphic House

The motivation for metamorphic houses is that many countries, including France, are going through socio-demographic evolutions, like growth of life expectancy and consequent increase in the number of elderly people, urbanization and resource scarcity. Households experience financial restrictions, while housing costs increase with the raise of real estate and energy prices [5].

Important questions arise concerning the future of housing policies and ways of living. We observe novel initiatives like participative housing and developing behaviors, including house-sharing, teleworking and longer stay of children in parents' homes.

To tackle the challenges raised by these emerging phenomena, future homes will have to be modular, upgradeable, comfortable, sparing of resources. They should be integrated in the urban context and exchange information with other homes, contribute to reducing the distances to be covered daily and respect the characteristics of the territory where they are located.

To reach these goals, metamorphic domestic environments will modify their shape and behavior to support activities and changes in life cycle of occupants, increase comfort and optimize the use of resources. Thanks to Information and Communication Technologies (ICT) and adaptive building elements, the same physical spaces will be transformed for different uses, giving inhabitants the illusion of living in bigger, more adapted and more comfortable places.

4.3. Automation in Smart City

The domain of Smart Cities is still young but it is already a huge market which attract 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 vehicle 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 remains 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. This help 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 exemple of smart city automated processes that will have to share information within the surrounding to make their decisions.

4.4. 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: data fusion for Smart Home and Smart Building

KEYWORDS: Smart home - Smart building

- Participants: Yoann Maurel and Frédéric Weis
- Partner: Université de Rennes 1
- Contact: Frédéric Weis
- URL: https://github.com/bpietropaoli/THEGAME/ (C-version)
- URL: https://bitbucket.org/TACOMA-irisa/java-bft (Java-version)

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 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. It is maintained and experimented within a sensor network platform developed by TACOMA since June 2013.

5.2. Platform Pervasive_RFID

KEYWORDS: Composite objects - RFID

- Participants: Paul Couderc and Anthony Blair
- Partner: Université de Rennes 1 (IETR)
- Contact: Paul Couderc

SCIENTIFIC DESCRIPTION

In 2016 we completed the RFID experiment testbed realized in 2014-2015 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).

5.3. Metamorphic Housing platform and Software

KEYWORDS: Smart Home - Metamorphic House

- Partner: Université de Rennes 1
- Partner: Université de Rennes 1 (Fondation Rennes 1)
- Contact: Michele Dominici and Frédéric Weis

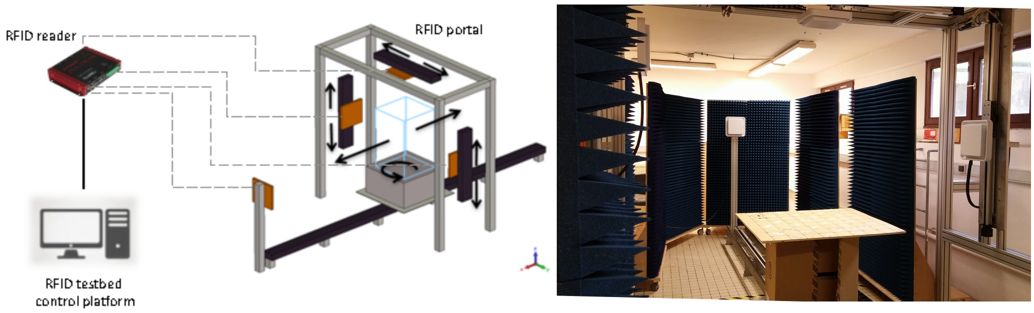


Figure 2. RFID testbed

SCIENTIFIC DESCRIPTION- SOFTWARE

As part of the experimentation of the On-demand room see 6.6, we have developed a software system that will be used to manage the room and provide functionalities to end users and building managers (access control, electrical and time consumption monitoring and report, room state display...). The software is expected to be deployed in the building that hosts the experimentation. This software is co-developed by Michele Dominici (University of Rennes 1), Guillermo Andrade (SED Inria) and Ghislain Nouvel (MobBI platform). Contributions might be provided by members of the Diverse project-team. Intellectual protection is expected to be applied on such software.

SCIENTIFIC DESCRIPTION- PLATFORM

In 2015, we realized a prototype of the on-demand room as an immersive interactive virtual-reality application, leveraging the Immersia platform (see https://raweb.inria.fr/rapportsactivite/RA2015/tacoma/uid29.html), with real domestic appliances connected to Immersa. In 2016, the experimentation of the On-demand room is organized in the following steps: modification of the original building to create a common, On-demand room between two apartments; deployment of the computer and hardware and software that we are developing; rental of the apartments to two households, for an estimated duration of one year. The building that will host the experimentation is showed in Figure 3. During the rental of the apartments, data will be collected and stored about the use of the room by households. Data will include time of occupation, mode (private or shared), consumptions, errors etc. The On-demand room will thus constitute an experimentation platform, where real people live and produce data that can be analyzed for statistical purposes. Produced data could also be used in combination with interviews of the occupants to improve the functionalities of the On-demand room, evaluate acceptance and appropriation.

5.4. ISO/IEC 15118-2 Open source Implementation

KEYWORDS: Smart Grid - Intelligent Transport System

- Partner: Telecom Bretagne
- Contact: Jean-Marie Bonnin

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

Figure 3. On-demand room real experimentation

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.

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.

6. New Results

6.1. RFID for pervasive computing environments

Participants: Nebil Ben Mabrouk, Frédéric Weis, Paul Couderc [contact].

Here the principle is to implement distributed data structure over a set of RFID tags, enabling a complex object (made of various parts) or a set of objects belonging to a given logical group to "self-describe" itself and the relation between the various physical elements. Some applications examples includes waste management, assembling and repair assistance, prevention of hazards in situations where various products / materials are combined etc. The key property of self-describing objects is, like for coupled objects, that the vital data are self-hosted by the physical element themselves (typically in RFID chips), not an external infrastructure like most RFID systems. This property provides the same advantages as in coupled objects, namely high scalability, easy deployment (no interoperability dependence/interference), and limited risk for privacy. However, given the extreme storage limitation of RFID chips, designing such systems is difficult:

- Data structures must be very frugal in terms of space requirements, both for the structure and for the coding.
- Data structures must be robust and able to survive missing or corrupted elements if we want to ensure the self-describing property for a damaged or incorrect object.

In the context of RFID system, the resiliency property of such data structures enables new information architecture and autonomous (offline) operation, which is very important for some RFID applications. We previously applied the self-describing objects approach to the waste management domain, which has shown to be a specially challenging situation for RFID. This challenge is found more generally in pervasive computing scenarios involving RFID reading in uncontrolled environments (see section 4.4).

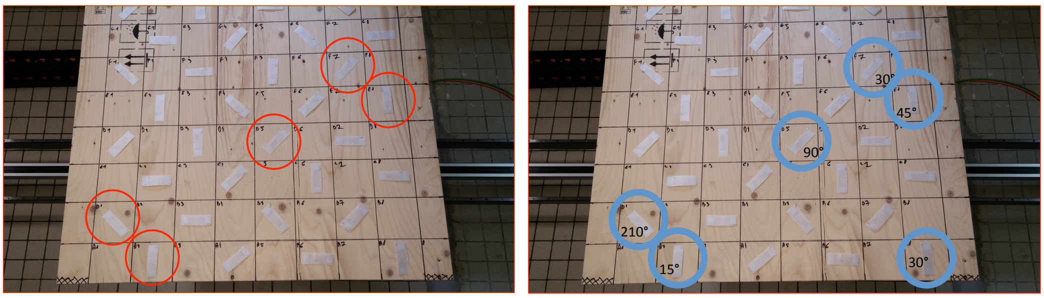
We achieved the following results:

- We showed the importance of diversity in the context of challenging RFID reading. A reconfigurable antenna was designed to support dynamic reading protocols.
- A software approach based on error correcting code was developed to support robust data storage in groups of RFID.
- An innovative RFID testbed for experimenting a large range of RFID situations/applications was operational (minus some features to be completed), supported by a simulation environment and a control environment.
- A patent was filed and some contacts made with RFID companies.

However, the supports for implementing dynamic reading protocols were lacking, both on the software and the radio side. The following further progress were made:

- The four elements diversity antenna designed in first phase was implemented.
- The control software has been greatly improved. A new environment was designed, offering powerful and flexible programming capabilities for easy prototyping of RFID reading scenarios and collecting experiments results. A simulator of the testbed was also developed, allowing off-site developments. This work is supported by the RFID-Lab ADT.
- Motion-induced improvements of RFID reliability were experimented, as shown below in Figure 4.
- A significant dissemination efforts toward the industry was made, and we have good hope that some of the contacts will lead to perspectives.

An example of motion-assisted RFID readings implemented is shown in figure 4: a matrix of 32 RFID tags are arranged in reduced power conditions, so that the tags are near their sensivity limit. In such conditions, 20% of the tags failed to be read by the reader. By coupling the reading with a rotation of 210 deg, we show that all the missing tags are progressively recovered.



(a) **(b)**

Figure 4. (a) initial read, 20% of the tags are missing (b) After 210 deg of rotation, all the tags are recovered

6.2. Building an extensible information sharing mechanism

Participants: Adrien Capaine, Yoann Maurel, Frédéric Weis [contact].

Context aware applications adapt their behavior based on information they can collect on their surrounding environment. Most of these data are provided by third-party software, sensors or computed by the application itself. A striking challenge facing the building of comprehensive pervasive system is the lack of integration between the different services provided by third parties. In this project, we intend to study and to provide mechanisms to enhance information sharing between applications and more specifically to augment information on the surrounding environment. The idea is to endow applications with the capability to increase or augment information on the physical world they are interacting with and to retrieve and share these data seamlessly depending on their location. Such mechanism aims at providing a complementary source of information in order to improve the process of choosing the best service/information provider and to help them keeping additional information on physical resources such as environment specific configuration (e.g., calibration data).

The idea of augmenting information on the physical world is not new. It has been done for centuries in the real world. For instance, the Little Thumb sowed pebbles to find his way just as hikers use cairns so as not to get lost. In daily life, people use sticky notes on pieces of hardware or objects to keep relevant information on their use or capabilities. Applied to IT, such ideas have been pushed by the augmented reality domain where users can access a personalized view of the real world that helps them to carry out their activities. Although this idea has already been implemented in some ad hoc solutions (to exchange ratings for instance), we aim to provide a more generic solution. Our solution must be applicable to nowadays devices and applications with little adjustment to the underlying architectures. It should then be flexible enough to deal with the lack of standards in the domain without imposing architectural choices. Such lack of standard is very common in IT and mainly due to well known factors : (1) for technical reasons, developers tends to think that their âstandardâ are better suited for their current use-case, or/and (2) for commercial reasons companies want to keep a closed siloed system to capture their users, or/and (3) because the domain is still new and evolving and no standard as emerged yet, or/and finally (4) because the problem is too complex to be standardized and most proposed standards tend to be bloated and hard to use.

We are currently implementing these ideas by designing and experimenting two architectures/prototypes:

- **Matriona** is a global distributed framework developed on top of OSGi. This project has been described in more details in the previous activity report. It is meant to be a comprehensive framework for exposing devices as REST-like resources. Resources functionalities can be extended through the mean of decorators. The system also provides access control mechanisms. The main interest of matriona concerning the information enrichment is its ability to support dynamic extension of resource meta-information by application and to provide means to share these meta-information with others. It implements the concept of group of interest with access control on meta-information. The concepts described in Matriona are in the process to be published.
- **Little Thumb Registry (LTReg)** is an independent resource registry that provides the same enrichment capabilities than Matriona but impose less constraints on the architecture of application. Although the prototype is operational, Matriona does not comply with the principle advocated herebefore: it supposes the use of a pivot technology (REST) and assumes that application developers will develop their application on top of on OSGi based platform. The idea behind LTReg is to decouple the registry from the framework and to provide a registry in the manner of Consul [1] with meta-information enrichment and sharing mechanisms. By focussing only on the discovery mechanism and information sharing, LTReg imposes fewer constraints on application and comply more with the goal of being ready to use in actual application. This is still a work in progress.

6.3. Modeling activities to promote self-consumption of locally produced energy

Participants: Jean-Marie Bonnin, Alexandre Rio, Yoann Maurel [contact].

[1] https://www.consul.io/

Traditional electricity distribution schemes decouple the production sources from the consumers so that it is necessary to transport energy over long distances. This type of organization is illustrated by the consumption of region such as Brittany, where 91% of the energy consumed is imported. It induces inherent inefficiencies due to the line losses and the transformation steps and therefore induces a high infrastructure and distribution cost. To face these problems and in order to reduce the environmental impacts associated with the use of energy, recent years have seen the development of initiatives to produce energy locally.

The sources of renewable energies are good candidates for this because they are varied and adapt easily to the different geographical situations. The infrastructures necessary for their implementation also impose fewer constraints in terms of installation and safety. One of the main obstacles to the unique use of these technologies comes from their strong dependence on physical and meteorological characteristics, which makes it more difficult to foresee production capacities. These characteristics vary from one facility to another and from one region to another. The combined use of these technologies therefore appears to be necessary to ensure that there will always be available energy at the lowest possible cost. In this context, OKWind proposes to deploy self-production units directly where the consumption is done and has developed expertise in multi-source energy production (see section 8.1).

In 2016, we started to study a solution favoring maximum autonomy of the instrumented sites from the traditional channels energy production by modeling business processes and using learning algorithms to shift demanding activities according to local production capacities. For example, the system should be able to anticipate a potential consumption of hot water (and thus of the energy needed for its production) in order to produce it at the best time when the renewable energy is available. It should also choose the best storage solution for this energy: hot water could be directly stored by the heat pump for instance. The system must implement policies that will intelligently shift demanding activities according to the predictions of energy production. It thus requires:

- **capabilities to predict the production of energy**. A lot of theoretical work has been done in the literature to predict the production of renewable sources of energy. In addition, in order to evaluate the production of energy and its consumption over time, OKWind has developed data retrieval mechanisms on each deployed sites. They produce accurate statistics on production and consumption. Both approaches should be used as inputs of our decision processes and model. One of our goals is to evaluate the precision of the theoretical prediction models against these real-world data to determine which are the most relevant for the implementation of our approach.
- **capabilities to model the consumption on energy**. Numerous works of the literature are interested in similar problems but focuses mainly on building electricity consumption model of machine tools [10]. We propose to focus instead on activity and business processes. In a related domain, modeling work has been conducted on water consumption of farms [7]. The objective was to predict the water consumption of an operating farm by modeling business processes. Our goal is to propose a similar model for electricity targeting a broader scope of economic sectors.
- **capabilities to schedule activities in order to match production and consumption so as to promote self-consumption.** This requires developing control loop that will proactively analyze and predict consumption and take measure to shift demand. This can, in a first approach, be done by assisting the consumers and providing them guidance on when to perform certain tasks. Assisted demand shifting have already been developed for the residential domain [6] but this project focused on uses mainly and little on the modeling of business processes. Ultimately, we would like to develop automated process transparently when possible. The learning algorithms will be developed in collaboration with Ubiant [2], a company specialized in artificial intelligence to smart-buildings.

To validate the approach and to understand business processes, we have started a field study targeting two types of activities (e.g. farm or hotel). We also want to develop tools to simulate a site so that we can quickly evaluate our policies over simulated long periods of time.

[2] https://www.ubiant.com/en/about/

6.4. Definition of a Smart Energy Aware architecture

Participant: Jean-Marie Bonnin [contact].

In the past years, energy demand has increased and shifted especially towards electricity as the form of consuming energy. As the number of electric devices constantly grows and energy production must increasingly rely on renewable sources, this leads into noteworthy disparity between electricity production and consumption. Within the ITEA2 12004 Smart Energy Aware Systems (SEAS) project (see section 1), we proposed the "SEAS Reference Architecture Model" (S-RAM). This architecture relies on four distributed services that enable to interconnect any energy actors and give them the opportunity to provide new energy services. The benefits of S-RAM have been studied on a specific use case, which aims to provide a service for estimating local photovoltaic production. It particularly helps energy management systems better plan electric consumption. The main principles of this architecture have been published and we developed several profs of concept that have been demonstrated in the project consortium. Our partner continue to develop the components of the architecture that will be demonstrated in the final review of the project.

6.5. Context modeling for Smart Spaces

Participants: Yoann Maurel, Frédéric Weis [contact].

To provide services for Smart Building, automation based on pre-set scenarios is ineffective: human behavior is hardly predictable and application should be able to adapt their behavior at runtime depending on the context. We focused on recognizing user's activities to adapt applications behaviors. Our aim is to compute small pieces of context we called *context attributes*. Those context attributes are diverse, for example a presence in a room, the number of people in a room etc. Building efficient and accurate context information using inexpensive and non-invasive sensors was and is still a great challenge. We proved, through the use of dedicated algorithms and a layered architecture that it is achievable when the targeted space (controlled environment) is known - due to the specific and non automated calibration process we used. Among all the available theories, we used the Belief Function Theory (BFT) [8] [9] as it allows to express **uncertainty** and **imprecision**.

Context is computed by a chain if three a tasks:

- The transition between a raw sensor value and a belief function is made through the use of a belief model which maps a sensor value to a belief function. A belief function represents the degree of belief associated to each possible value of the context attribute.
- Then a set of belief functions (corresponding to a set of sensors) can be combined (fused).
- Finally the system can decide what is the "best" value for the context attribute.

Currently the BFT theories requires a huge calibration process. In 2016, we obtained new results on the semi-automated building of belief functions, that have to be provided by each sensor, using our BFT Java implementation (see section 5.1).

6.6. Towards Metamorphic Housing: the on-demand room

Participants: Frédéric Weis, Michele Dominici [contact].

6.6.1. A concrete example of Metamorphic Housing: the on-demand room

The research activities related to the research program on Metamorphic Housing mainly focused on defining the detailed architecture and functionalities of the selected case study, the on-demand room. We conducted an iterative co-design process, involving the partners of the chair "Habitat Intelligent et Innovation". Valuable input was also obtained by collaborating with Delta Dore, LOUSTIC, Université de Bretagne Occidentale, etc. The result was the identification of the needs of end users, building owners and managers with respect to the on-demand room. To satisfy these requirements, we proposed a system architecture, combining computer and mobile applications with domotic equipments and novel interaction means for end users.

These are inspired by the Pervasive Computing and Interactive Architecture principles, where a continuous and implicit interaction between occupants and the physical world is made possible by augmented architectural structures, which sense the natural actions of people and respond accordingly. In this way, the occupants of the dwellings equipped with on-demand room experience a new form of housing, stimulating social interactions between neighbors and satisfying periodic needs of additional housing surface, as we illustrated in [4]. We submitted our system architecture, novel interaction means and augmented structure designs to the industrial property services of Inria and University of Rennes 1, which are currently evaluating the possibility of establishing patent protection on these inventions.

6.6.2. Experimentation of Metamorphic Housing on social housing

We helped Néotoa, a social landlord, preparing and initiating an experimentation of the on-demand room on one of their residential buildings. For this, we built and coordinated a consortium of partners working on the project: Veolia, CCI Rennes, Cardinal Edifice, Rennes Métropole, Néotoa, Delta Dore, LOUSTIC, Université de Bretagne Occidentale, MobBI platform (University of Rennes 1), Inria, Institut de Gestion de Rennes. We took a user-centered approach to the problem, studying it from several points of view and mobilizing several disciplines: psychology and ergonomics (LOUSTIC), sociology (Université de Bretagne Occidentale), marketing (Institut de Gestion de Rennes). We conducted user interviews, initially leveraging the demonstrator of the on-demand room that we previously built via the Immersia virtual reality platform. Then, we ran on-line inquiries to reach a larger audience. We took into account the lessons that we learned in the design and development of a computing and domotic system, leveraging the expertise of valuable partners (Delta Dore, MobBI platform, Inria), as detailed in section 5.3.

7. Bilateral Contracts and Grants with Industry

7.1. SIMHet

Partner: YoGoKo

Starting: Nov 2015; ending: Oct 2018

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, this smart mechanism will give competitive advantage for YoGoKo over its competitors.

8. Partnerships and Cooperations

8.1. Regional Initiatives

Project: Modélisation des activités de site consommateur d'énergie pour favoriser l'autoconsommation d'énergies renouvelables produites localement

Partner: OKWIND

Starting: Nov 2016; ending: Nov 2019

Abstract: OKWind [3] is a company specialized in local production of renewable energy. This project, with Inria DiverSE and TACOMA 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.

Project: EkoHub

Partners: Ekolis, Delaye transport

Starting: Nov 2014; ending: Nov 2017

Abtract: The EkoHub project has been architectured around hors multi-technologies gateway and leverages on the one developped in the ITSSv6 European project. In addition to the multiple interfaces of our platforms, sensor devices have been incorporated into the project and we studied different scenarios elaborated with our professional partners (Layaye Logistics). Intelligent data management schemes are being studied to adapt to the communication environment and the needs of the application consuming the data.

8.2. National Initiatives

Project: Pervasive_RFID

Partner: IETR

Starting: July 2013; ending: July 2016

Abtract: Pervasive_RFID is a joint effort (within the CominLabs initiative, see http://www.cominlabs.ueb.eu/) started in July 2013 with IETR (institut d'électronique et de télécommunications de Rennes) to study and design innovative RFID reading protocols in the context of pervasive computing applications. 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.

Project: GLIE - Guidage Lumineux par l'Intelligence de l'Environnement

Partner: OyaLight

Starting: December 2014; ending: April 2016

Abstract: GLIE is a collaborative projet with OYALIGT and TACOMA group. The objective of the project is to design and demonstrate a new service combining connected LEDs provided by OYALIGHT and a software tool developed by TACOMA. By integrating and analyzing data transmitted by the sensors integrated into LEDs, the service must be able to detect a given context and to react accordingly.

Project: Greenfeed

http://greenfeed.org

Partner: BeNomad, Mines St Etiennes, Enedis, G2MOBILITY, GreedPocket

Starting: July 2013; ending: Nov 2016

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

Abstract: Greenfeed aims at improving electro-mobility, which means the ease with which users can travel using electric cars. In order to achieve its goal, the project focuses three main operators: electro-mobility service provider (EMSP), distribution service operator (DSO), and charging station operator (CSO). During the project, the role of these actors have been precisely defined, so were the role of the systems they were in charge of. A great effort has been put on interoperability, so that the developed systems could collaborate with each other. One of the key use case was to enable the smart management of available power on a 10 charging site. This led to a demonstration in which a Renault Zoé, customized by the Institut Védécom, was able to negotiate a charge planning with the electric power grid. Then a grid initiated renegotiation was demonstrated, once the initial smart charging process had began. This was the first time this behavior had been achieved with a vehicle in France.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Project acronym: SCOOP@F part 2

Partners: MEDE, Renault, PSA

Starting: January 2016; ending: Dec 2018

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 (ongoing) and SCOOP@F Part 2 from 2016 to 2018. 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).

8.3.2. Collaborations in European Programs, Except FP7 & H2020

Project acronym: SEAS (ITEA3)

Partners: Telecom Paris Tech, Telecom Saint Etienne, Mines Saint Etienne, Engie, Kerlink, BeNomad, ICAM, CNR, VTT

Starting: Feb 2014; ending: Jan 2017

Abstract: The SEAS project addresses the problem of inefficient and unsustainable energy consumption, which is due to a lack of sufficient means to control, monitor, estimate and adapt the energy use of systems versus the dynamic use situations and circumstances influencing the energy use. The objective of the SEAS project is to enable energy, ICT and automation systems to collaborate at consumption sites, and to introduce dynamic and refined ICT-based solutions to control, monitor and estimate energy consumption. Proposed solution should enable energy market participants to incorporate micro-grid environments and active customers. We are involved in the project to design a distributed system architecture and to implement two proofs of concept: the first one is related to the electric vehicle charging and the other one to the prevision of solar energy production.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- PC member for Ehpwas 2016: 4th IEEE Int. Workshop on E-Health , 2016, F. Weis
- PC member of The 83th IEEE Vehicular Technology Conference, 15-18 May 2016, Nanjing, China, JM. Bonnin
- PC member of EAI International Conference on Mobile Medical Multimedia Technologies, Applications and Services, 14-15 June 2016, Budapest, Hungary, JM. Bonnin
- PC member of 13th African Conference on Research in Computer Science and Applied Mathematics, 11 - 14 October 2016, Tunis, Tunisia, JM. Bonnin
- PC member of The 84th IEEE Vehicular Technology Conference, 18-21 September 2016, Montreal, Canada, JM. Bonnin

9.1.2. Scientific Events Selection

9.1.2.1. Reviewer

- Mobile Networks and Applications, JM. Bonnin
- IEEE transactions on Mobile Computing, JM. Bonnin
- Simulation Modeling Practice and Theory, JM. Bonnin
- Computer Standards & Interfaces, an international journal on Engineering Science and Technology, JM. Bonnin

9.1.3. Invited Talks

- Keynote speech at the 6th NGNS international conferences, 17/12/2016, Rabat, Morocco, JM. Bonnin
- Invited talk at the Drive for All seminary, 31/08/2016, Paris, France, JM. Bonnin
- RFIDay Event, June 2016, Vitré. Talk and demos, P. Couderc
- Invited talk at the BMW Summer School, "New Business, New Mobility - YoGoKo case study", July 2016, Tegernsee, Bavaria, Germany, JM. Bonnin
- SESAME school of Tunis, Nov 2016, Tunis, Tunisia, JM. Bonnin
- Invited Talk at Smart Systems inter Labex Symposium, November 2016, Besançon, P. Couderc
- ENSAM school of Meknes, Dec 2016, Meknes, Morocco, JM. Bonnin

9.1.4. Leadership within the Scientific Community

- Jean-Marie Bonnin is member of the scientific council of the GIS ITS
- Jean-Marie Bonnin is member of the scientific council the Id4Car cluster
- Jean-Marie Bonnin is an elected member of the Scientific Council of IMT

9.1.5. Scientific Expertise

- Evaluation committee for the Belgium government, JM. Bonnin
- Expert for ANR, F. Weis and JM Bonnin
- Expert for CSV board of "Pôle Images et Réseaux", P. Couderc

9.1.6. Research Administration

- Head of the Networks, Telecommunication and service department at IRISA, JM. Bonnin

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

L2/L3: network computing (lectures, tutorials, labs), 250 hours, F. Weis, University Rennes 1

Master: Wireless LANs, F. Weis, 20 hours, M2, Telecom Bretagne

Master: Supervision of a Master 1 project related to the smart building (in collaboration with Myriads), 48 hours, P. Couderc, University Rennes 1

Master 2: Pervasive computing introduction course, Paul Couderc, 4 hours, University Rennes 1

Master 1: Network programming (lectures, tutorial, labs), 78 hours, Y. Maurel

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

9.2.2. Supervision

PhD in progress: Adrien Capaine, Vers une plate-forme de LED connectées comme vecteur de services contextuels dans le cadre des bâtiments intelligents, 01/05/15, Frédéric Weis and Yoann Maurel

PhD in progress: Zaineb Lioune, Une Architecture pour des Services e-Santé évolutifs dans le cadre des Maisons Intelligentes, 01/09/14, Frédéric Weis, Tayeb Lemlouna and Philippe Roose

PhD in progress: Indra Ngurah, Protocoles de routage pour l'ITS, 01/05/16, Jean-Marie Bonnin

PhD in progress: Christophe Couturier, Exploitation de mécanismes EDGE pour l'ITS, 01/11/16, Jean-Marie Bonnin

PhD in progress: Alexandre Rio, Modélisation des activités de site consommateur d'énergie, 01/10/16, Olivier Barais and Yoann Maurel

9.2.3. Juries

Clément DUHART, "Toward Organic Ambient Intelligences ? EMMA", University du Havre, F. Weis, PhD referee

Minh Huong NGUYEN, "Contribution to Intelligent Transportations Systems: Security of Safety applications in Vehicular Ad hoc Networks", JM Bonnin, PhD referee

Matthieu KANJ, "Intelligent Supervision of Flexible Optical Networks", JM Bonnin, Président

9.3. Popularization

- Invited talk at the Telecom ParisTalks on "De la voiture connectée à la voiture autonome", "Le véhicule autonome, un véhicule ultra-communicant", March 2016, Paris, France, JM. Bonnin
- Invited talk at the A3C7 public event: "L?automobile intelligente et communicante: Carminat, GPS et demain?", "L?automobile communicante dans la ville", June 2016, Cesson-Sévigné, France, JM. Bonnin
- Invited talk at the workshop "Atelier Cybercriminalité dans les transports - Véhicule autonome et transport connecté : quelles stratégies de fiabilité et de sécurité ?","Sécurité des Communications pour les ITS", June 2016, Angers, France, JM. Bonnin
- "Les véhicules autonomes seront communicants?, Revue TELECOM 182, Oct 2016, JM. Bonnin
- Special issue TPC for Revue TEC mobilité intelligente : "Routes & Véhicules : Quelles Connexions ?", Nov 2016, JM. Bonnin
- "Standards et ITS : vers un écosystème ouvert ?", Revue TEC Mobilité intelligente, Nov 2016, JM. Bonnin
- "Quand les modes de vie actuels façonnent l'habitat du futur", Site Internet Batiactu, Jan 2016, http://www.batiactu.com/edito/quand-modes-vie-actuels-faconnent-habitat-futur-43438.php
- Invited talk "Le logement évolutif, Michele Dominici", Matin de l'aura angevine, Jan 2016, Angers
- Cardinal Edifice imagine l'habitat de demain, Communiqué de presse de Cardinal, relayé sur le site Batinfo, Jan 2016. http://batinfo.com/actualite/cardinal-edifice-imagine-lhabitat-de-demain_4339

- Invited talk "Ville et Habitat intelligent : des innovations au service du vivre-ensemble ?", Michele Dominici, Feb 2016, La Friche la Belle de Mai, Marseille
- "Place au logement caméléon - freemium" - Métiers. LeMoniteur, 1 mars 2016. http://www.lemoniteur.fr/articles/place-au-logement-cameleon-31516795
- Invited talk "L'habitat d'hier, d'aujourd'hui et de demain, intervention de Michele Dominici", Apr 2016 dans le cadre du Printemps du Développement Durable, Langueux
- Ecole d'été "Ecologie et biens communs", Université de Bretagne Occidentale, Sept 2016, Michele Dominici

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Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] F. J. ACOSTA PADILLA. *Self-adaptation for Internet of Things applications*, Université de Rennes 1, France, December 2016, https://hal.inria.fr/tel-01426219

International Conferences with Proceedings

[2] Z. LIOUANE, T. LEMLOUMA, P. ROOSE, F. WEIS, M. HASSANI. *A Genetic–based Localization Algorithm for Elderly People in Smart Cities*, in "The 19th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems", Malte, Malta, November 2016, https://hal.inria.fr/hal-01372772

[3] Z. LIOUANE, T. LEMLOUMA, P. ROOSE, F. WEIS, M. HASSANI. *A Markovian-based Approach for Daily Living Activities Recognition*, in "The International Conference on Sensor Networks (SENSORNETS'16)", rome, Italy, February 2016, https://hal.inria.fr/hal-01280001

Research Reports

[4] M. DOMINICI, M. BANÂTRE. *Virtualizing the physical world: the on-demand room case study*, Irisa, October 2016, n^o 2039, https://hal.inria.fr/hal-01417204

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[5] R. BALDONI, M. BANÂTRE, M. DOMINICI, D. DUMORTIER, M. EL MANKIBI, M. FRÉJUS, B. KOLDEHOFE, M. MECELLA, K. ROTHERMEL, P. SUIGNARD. *Comfort-Oriented Metamorphic House (COMETAE)*, October 2012, n^o PI 1998, Publications Internes de l'IRISA ISSN : 2102-6327, https://hal.inria.fr/hal-00864884

[6] J. BOURGEOIS. *Interactive Demand-Shifting in the Context of Domestic Micro-Generation*, The Open University ; Université de Rennes 1 [UR1], June 2016, https://hal.inria.fr/tel-01385022

[7] J.-M. BRUEL, B. COMBEMALE, I. OBER, H. RAYNAL. *MDE in Practice for computational science*, in "Procedia Computer Science", 2015, vol. 51, pp. 660–669

[8] B. PIETROPAOLI, M. DOMINICI, F. WEIS. *Propagation of Belief Functions through Frames of Discernment : Application to Context Computing*, in "The 26th International FLAIRS Conference", St. Pete Beach, United States, May 2013, https://hal.inria.fr/hal-00927088

[9] B. PIETROPAOLI, M. DOMINICI, F. WEIS. *Virtual Sensors and Data Fusion in a Multi-Level Context Computing Architecture*, in "16th International Conference on Information Fusion (FUSION 2013)", Instanbul, Turkey, July 2013, https://hal.inria.fr/hal-00927092

[10] L. ZHOU, J. LI, F. LI, Q. MENG, J. LI, X. XU. *Energy consumption model and energy efficiency of machine tools: a comprehensive literature review*, in "Journal of Cleaner Production", 2016, vol. 112, pp. 3721–3734