Activity Report 2017

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, end of the Team: 2017 December 31

Keywords:

Computer Science and Digital Science:

A1.2. - Networks
A1.2.5. - Internet of things
A1.2.6. - Sensor networks
A1.2.7. - Cyber-physical systems
A1.3. - Distributed Systems
A1.4. - Ubiquitous Systems
A2.3. - Embedded and cyber-physical systems
A2.3.2. - Cyber-physical systems
A2.5. - Software engineering
A2.5.1. - Software Architecture & Design
A2.5.3. - Empirical Software Engineering
A2.6. - Infrastructure software
A2.6.1. - Operating systems
A2.6.2. - Middleware
A4.8. - Privacy-enhancing technologies
A5.11. - Smart spaces
A5.11.1. - Human activity analysis and recognition
A5.11.2. - Home/building control and interaction

Other Research Topics and Application Domains:

B3.1. - Sustainable development
B3.1.1. - Resource management
B4.4. - Energy delivery
B4.4.1. - Smart grids
B4.5.2. - Embedded sensors consumption
B6.1. - Software industry
B6.1.1. - Software engineering
B6.1.2. - Software evolution, maintenance
B6.2.2. - Radio technology
B6.3.3. - Network Management
B6.4. - Internet of things
B6.6. - Embedded systems
B7.2. - Smart travel
B7.2.1. - Smart vehicles
B7.2.2. - Smart road
B8.1. - Smart building/home
B8.1.1. - Energy for smart buildings
B8.1.2. - Sensor networks for smart buildings

B8.2. - Connected city
B8.5.2. - Crowd sourcing
B8.5.3. - Collaborative economy
B9.8. - Privacy
B9.10. - Ethics

1. Personnel

Research Scientist
Paul Couderc [Inria, Researcher]

Faculty Members
Jean-Marie Bonnin [Team leader, IMT Atlantique (Cesson-Sévigné), Professor, HDR]
Yoann Maurel [Univ. Rennes I, Associate Professor]
Frédéric Weis [Univ. Rennes I, Associate Professor, HDR]

Post-Doctoral Fellow
Djibrilla Amadou Kountche [IMT Atlantique (Cesson-Sévigné), until Sep 2017]

PhD Students
Christophe Couturier [IMT Atlantique (Cesson-Sévigné), PhD student]
Adrien Capaine [OyaLight, PhD Student, granted by CIFRE]
Indra Ngurah [IMT Atlantique (Cesson-Sévigné)]
Alexandre Rio [OKWIND, granted by CIFRE]
Rodrigo Silva [IMT Atlantique (Cesson-Sévigné)]
Liouane Zaineb [Co-tutelle Univ. Rennes 1 with Univ. Monastir, until Oct 2017]

Technical staff
Michele Dominici [Univ. Rennes I, until Mar 2017]
Xavier Gilles [IMT Atlantique (Cesson-Sévigné), from Mar 2017 until Nov 2017]
Guillaume Habault [IMT Atlantique (Cesson-Sévigné), from Mar 2017 until Aug 2017]
Guillaume Le Gall [IMT Atlantique (Cesson-Sévigné), until Nov 2017]

Interns
Yasmina Andaloussi [CNRS, from Apr 2017 until Sep 2017]
Jules Desjardin [Inria, from Oct 2017]

Administrative Assistant
Fabienne Cuyollaa [Inria]

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 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

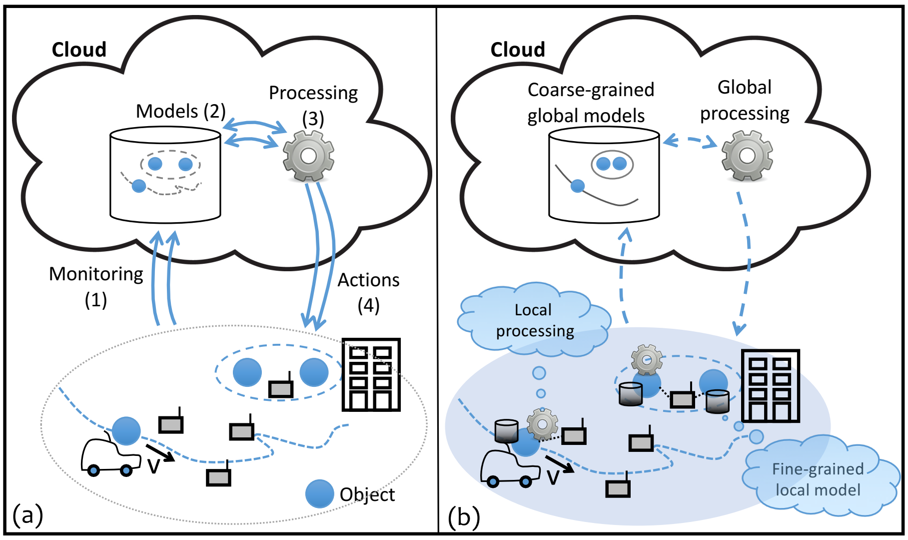

Figure 1. Adaptation processes in pervasive environments

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

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 [6].

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

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

KEYWORDS: Composite objects - RFID

- Participants: Paul Couderc and Anthony Blair (Univ. Rennes 1)
- Partner: Univ. Rennes 1 (IETR)
- Contact: Paul Couderc

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).

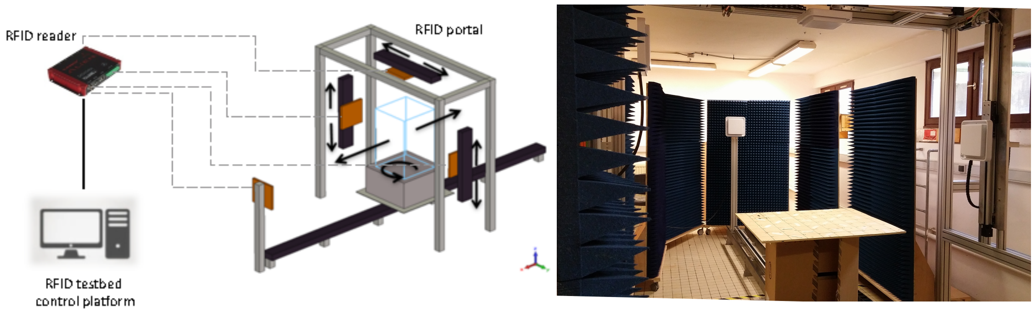

Figure 2. RFID testbed

5.3. Metamorphic Housing platform and Software - On-demand room

KEYWORDS: Smart Home - Metamorphic House - Sharing

- Participants: Ghislain Nouvel (Univ. Rennes 1), Guillermo Andrade Barroso and Michele Dominici
- Partner: Univ. Rennes 1
- Partner: Delta Dore - Néotoa [1]
- Contact: Michele Dominici and Frédéric Weis

SCIENTIFIC DESCRIPTION- SOFTWARE

As part of the experimentation of the On-demand room, 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 has been deployed in the building that hosts the experimentation. This software is co-developed by Michele Dominici (Univ. Rennes 1), Guillermo Andrade (SED Inria) and Ghislain Nouvel (MobBI platform [2]). Contributions are provided by members of the Diverse project-team. Intellectual protection is expected to be applied on such software.

SCIENTIFIC DESCRIPTION- PLATFORM

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 2016-2017, 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 hosted the experimentation is showed in Figure 3. During the rental of the apartments, data has been collected and stored about the use of the room by households. Data included time of occupation, mode (private or shared),

[1] http://www.neotoa.fr/
[2] https://mobbi.univ-rennes1.fr/

consumptions, errors etc. The On-demand room thus constitutes 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.

Figure 3. On-demand room real experimentation

5.4. ISO/IEC 15118-2 Open source Implementation

KEYWORDS: Smart Grid - Intelligent Transport System

- Partner: IMT Atlantique
- Participants: Guillaume Le Gall
- 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 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 [3].

6. New Results

6.1. Smart City and ITS

Participants: Indra Ngurah, Djibrilla Amadou Kountche, Xavier Gilles, Christophe Couturier, Rodrigo Silva, Frédéric Weis, Jean-Marie Bonnin [contact].

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

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 organisation 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 autonomie cover 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 benefits 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 rely 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.

We participated in the definition of the distributed architecture that has been adopted by all partners of the SEAS project. 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 developed the components of the architecture that has been demonstrated in the final review of the project (in January). The principles of the architecture and data representation has been used to design an open reusable Data Manager in the context of the EkoHub projet. This modular software will be extended to fit the needs of Indra Ngurah and Rodrigo Silva works.

6.2. Convergence middleware for pervasive data

Participants: Yoann Maurel, Jules Desjardin, Paul Couderc [contact].

We are currently working on data driven middleware approaches dedicated to physical objects and smart spaces. We had previous contributions on the topic, where opportunistic collaborations between mobile devices were supported by Linda-like tuple space and IEEE 802.11 radios. However, these were adapted to relatively complex devices and the technological limitation at the time did not allow the full potential of the model. More recently, we investigated distributed storage spread over physical objects or fragments using RFID, enabling complex data to be directly reflected by passive objects (without energy). Yet other radio technologies, such as BLE, are emerging to support close range interactions with very low (or even zero) energy requirements.

Applications such as pervasive games (for ex. Pokemon Go), on the go data sharing, collaborative mobile app are often good candidates for opportunistic or dynamic interaction models. But they are not well supported by existing communication stacks, especially in context involving multiple technologies. Technological heterogeneity is not hidden, and high level properties associated with the interactions, such as proximity/range, or mobility-related parameters (speed, discovery latency) have to be addressed in an ad hoc manner. We think that a good way to solve these issues is to offer an abstract interaction model that could be mapped over the common proximity communication technologies, in a similar way as MOM (Message Oriented Middleware) such as MQTT abstract communications in many IoT and pervasive computing scenarios. However, they typically requires IP level communication, which far beyond the capabilities of ultra low energy proximity communication such as RFID and BLE. Moreover, they often rely on a coordinator node that is not adapted in highly dynamic context involving ephemeral communications and mobile nodes.

We started the implementation of an associative memory mechanism over BLE, as it is a common ground that can be shared with passive or semi passive communications (RFID, NFC). Such mechanism, although relatively low level, is still a very useful building block for opportunistic applications: it enables opportunistic data storage/sharing and signaling/synchronization (in space in particular). This approach is fully in line with more general trend developed in the team to build "smart" systems leveraging local resources and data oriented mediation. We have started validation work with a few applications, in particular regarding energy aspects and scalability with respect to the communication load. This should lead to publishing on both infrastructure and application level aspects of the approach.

6.3. Modeling activities and forecasting energy consumption and production to promote the use of self-produced electricity from renewable sources

Participants: Alexandre Rio, Yoann Maurel [contact].

This work began in 2017 and is carried out as part of a broader collaboration between Tacoma, the Diverse Team and OKWind, a company specialized in the production of renewable sources of energy. OKWind proposes to deploy self-production units directly where the consumption is done. It has developed expertise in vertical-axis wind turbines, photovoltaic trackers, and heat pump. This project 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. The goal is to favor the consumption of locally produced electricity and to maximize the autonomy of the equipped sites so as to reduce the infrastructure needed to distribute electricity, to set energy cost, and to reduce the ecological impact of energy consumption.

Modeling and forecasting production and consumption of a site is hard and raises several issues: how to precisely assess the consumption and production of energy on a given site with changing conditions ? How to adequately size energy sources and energy storage (wind turbine, solar panel and batteries) ? And what methods to use to optimize consumption and, whenever possible, act on installations and activities to reduce energy costs ? We aim to propose tools to predict the consumption of a site based on estimation and previous observation, monitor the site in real time and forecast evolution. We propose to build a DSL describing consumption and production processes, and a system providing recommendations based on the derived model at runtime.

The problem of forecasting is known from both a production and consumption point of view. OKWind has developed tools to predict the production of their renewable sources - the same goes for batteries - and a lot of theoretical work has been done on consumption in the literature. In our view little has been done to precisely model activities, their energy consumption and the associated variability. Indeed most of the current approaches are concerned with either large-scale forecasting for the Smart Grid, are based on coarse grain data (total energy consumption of the site), or focuses on modeling specific appliance without describing how and when they are used.

This is paradoxical considering that companies have spent a lot of time modeling their activities from a logistic point of view. Intuitively, the predictable and seasonal nature of a company's activities would allow building activity schedulers that favor the consumption of certain energy sources (the cleanest or least expensive one for instance). The development of a DSL to describe the relationships between activities, their planning, and the production and environmental factors would make possible to simulate a given site at a given location, to make assumptions on sizing, and would be a basis to forecast energy consumption so as to provide recommendations for the organization of activities.

We already have developed part of this DSL that simulates activities and production. In particular, it is capable of simulating consumption and production over a given period based on available environmental data. This tool is in the experimentation phase. In particular, we are collecting information on several sites to measure the consumption of various activities.

6.4. Sharing knowledge and access-control

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

Smart spaces (Smart-city, home, building, etc.) are complex environments made up of resources (cars, smartphones, electronic equipment, applications, servers, flows, etc.) that cooperate to provide a wide range of services to a wide range of users. They are by nature extremely fluctuating, heterogeneous, and unpredictable. In addition, applications are often mobile and have to migrate or are offered by mobile platforms such as smartphones or vehicles.

To be relevant, applications must be able to adapt to users by understanding their environment and anticipating its evolutions. They are therefore based, explicitly or implicitly, on a representation of their surrounding environment based on available data provided by sensors, humans, objects and applications when available. The accuracy of the adaptations made by the applications depends on the precision of this representation. Building and maintaining such knowledge is resource-intensive in terms of network exchanges, computing time and incidentally energy consumption. It is, therefore, crucial to find ways to improve this process. In practice, many applications build their own models without sharing them or delegating calculations to remote services, which is not optimal because many processes are redundant. A huge improvement would be to find mechanisms that allows sharing the information so as to reduce as much as possible the treatments necessary to obtain it.

However, it seems extremely complex to provide a global, complete and unified view of the environment that reflects the applications' concerns. If it were possible, such a single representation would by nature be incomplete or subjective. Our solution should be applicable to nowadays devices and applications with little adjustments 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 tend to think that their "standard" is 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. The IoT domain suffers from all of these impediments and solution targeting mid-term application have to take these factors into accounts. Many IoT applications are still organized in silos of information. This leads to the deployment of sensors with similar functions and redundant pieces of software providing exactly the same service. Many frameworks or ontologies have been developed in the field to provide a solution to this problem but their implementation depends on the goodwill of the companies who do not always see their interest in losing part of the control of their application and data. To be largely accepted, solutions should let companies decide what information to share and when with little impact on their current infrastructure.

We want to be able to develop collaborative mechanisms that allow applications to share some of their information about the immediate surrounding environment with their counterparts. The idea is to allow the construction of shared representations between groups of applications that manipulate the same concepts so that each group can construct a subjective and complete representation of the environment that corresponds to its concerns. In this context, we want to offer applications mechanisms allowing them to leave information about their environment by associating them directly with the flows, data, services and objects handled. This information will be stored by the environment so that it will be possible for the application to retrieve it and for its peers to access it. From a logical point of view, applications will have the illusion of annotating objects directly; we make no assumptions about where this information will be stored, which will depend on the characteristics of the environment or the sharing solution chosen. Data should be stored as close as possible to the environments they qualify for reasons of performance, confidentiality and autonomy. To experience that idea, we have developed:

- Matriona, a globally 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 global framework for exposing devices as REST-like resources. Resources functionalities can be extended through the mean of decorators. The system also provides access mechanisms. The main interest of Matriona with regards to the information enrichment is its ability to support the dynamic extension of resource meta-information by application and to provide means to share this meta-information with others. It implements the concept of groups of interest with access control on meta-information. The concept described in Matriona are in the process to be published.

- Little Thumb Base (LithBase) is an independent knowledge base that provides the same enrichment capabilities than Matriona but imposes fewer constraints on the architecture of applications. It is a shared database implemented on simple low power nodes (esp32) that are cheap to deploy, flash and use. The idea behind LithBase is to decouple the storage from the framework and to provide a standard mechanism to share information. Ultimately we want to use its capabilities to implement a registry in the manner of Consul with meta-information enrichment and sharing mechanisms. By focussing only on the discovery mechanism and information sharing, LithBase imposes fewer constraints on applications and comply more with the goal of being ready to use in existing applications. This is still a work in progress. This solution also raises the issue of trust and control over access to this information. It is indeed necessary for applications to be able to determine the source of the additional information and to determine who will have access to the information they add. We have also been experimenting with access control mechanism that is implemented by LithBase. We are currently using elliptic cryptography to allow private information sharing between groups. Ultimately the goal of this project is to produce a coordinating object that implements generic mechanisms favouring opportunistic behaviours of surrounding applications.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

Project: SIMHet

Partner: YoGoKo

Starting: Nov 2015; Ending : October 2018

Contact: JM Bonnin

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.

8. Partnerships and Cooperations

8.1. Regional Initiatives

Project: EkoHub

Partner: Ekolis, Delaye transport, Telecom Bretagne

Starting: Nov 2014; Ending : Nov 2017

Contact: JM Bonnin

Abstract: The EkoHub project has been architectured around our multi-technologies gateway and leverages on the one developed 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. The data model has been derived from the outcomes of the SEAS project.

The final EkoHub demonstration held in november 2017 with project partners.

8.2. European Initiatives

8.2.1. Collaborations in European Programs, Except FP7 & H2020

Project: SCOOP@F part 2

Partner: MEDE, Renault, PSA

Starting: Jan 2016; Ending : Dec 2018

Coordinator: JM Bonnin

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). 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).

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

Contact: JM Bonnin

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.

Project: SCHIEF

Partner: TUM (Technical University of Munchen), IMT Atlantique, Eurecom

Starting: Sept 2016; Ending : Dec 2018

Coordinator: JM Bonnin

Abstract: In SCHEIF, we create a pilot for an enabler platform for the industrial Internet of Things. We envision a three-layered architecture with Sensors and actuators on the lowest layer. This layer includes industrial robots. On top of this hardware layer we envision site-local processing of data. Such a processing is beneficial since it allows keeping latency boundaries on the one hand and being in full control of all data on the other hand. The latency is relevant for enabling diverse time-critical operations as they often happen in industrial production environments. The local processing is relevant for protecting data. A privacy-conform processing is required to protect company secrets and to protect the privacy of workers. The third layer comprises data processing in the cloud. We envision mostly local data processing. However, offloading computing tasks to public or private clouds will be relevant for compute-intense tasks and those tasks that require coordination between production sites. The main scenario of SCHEIF is an industrial production site where mobile robots and human workers coexist. The focus is providing the data required to manage and optimize the production process always at the most suitable quality. The suitability of data relies on the requirements of the data producers and consumers. A planned demo scenario is a provoked system crash that leads to reprioritization of data streams to mitigate from the failure.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- Co-organizer of a local IoT conference, Technoconference 22, IoT et si on connectait le monde: enjeux d'aujourd'hui et de demain, October 5th 2017 - Rennes, P. Couderc.

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

9.1.2.2. Member of the Conference Program Committees

- PC member for VTC, NGNS, CARI, ICON, ICIN, JM Bonnin

9.1.3. Invited Talks

- Invited talk at DATE 2017: "Which interaction models between objects for smarter spaces?", JM Bonnin
- Invited talk at ENOVA (16/03/2017) Strasbourg: "BMS et charge intelligente de véhicule électrique: une introduction au protocole ISO/IEC 15118", JM Bonnin
- Invited tutoriel at Digicosme (Saclay) summer school: "Foster digital innovation in Smart Cities", JM Bonnin
- Invited talk at UTS (22/08/2017): "Fostering digital innovation in Smart Cities and Cooperative autonomous vehicle", JM Bonnin
- Invited talk at Technoconference, IoT et si on connectait le monde: enjeux d'aujourd'hui et de demain: "Développement d'applications pervasives dans un environnement IoT", F. Weis

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
- Jean-Marie Bonnin is a scientific advisor of the YoGoKo startup

9.1.5. Scientific Expertise

- Evaluation committee for the Belgium government, JM. Bonnin
- Expert for ANR, F. Weis and JM Bonnin
- Evaluation committee for the CADO (PME Business) challenge (Id4Car, I&R), 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, Univ. Rennes 1

Master: Wireless LANs, F. Weis, 20 hours, M2, IMT Atlantique

Master: Supervision of a Master 1 project related to the smart building (in collaboration with Myriads), 22 hours, P. Couderc, Univ. 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, Car-based Data Collection for Low Energy Devices (Car-based DC4LED), 01/05/16, Jean-Marie Bonnin

PhD in progress: Christophe Couturier, Frugal networking for cooperative autonomy, 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

PhD in progress: Rodrigo Silva, Mécanisme de décision multi-critères pour le placement de flux en environnement hétérogène et changeant, 1/11/15, Jean-Marie Bonnin

9.2.3. Juries

Adrien Carteron, "Une approche événementielle pour le développement de services multi-métiers dédiés à l'assistance domiciliaire", Univ. Bordeaux, F. Weis, PhD referee

Amina BOUDENDIR , "Virtual Network Functions modeling for Dynamic Network-as-a-Service: Architecture principles and deployment", JM Bonnin, PhD referee

Ikbel Daly, JM Bonnin, PhD referee

9.3. Popularization

Under the leitmotif "testing and learning about digital mobility solutions in Rennes", Rennes Metropole will open the doors of its city from March 14 – 18, 2018 for a new type of inclusive and collaborative event experience, dedicated to transforming mobility services: inOut! Composed of two distinct but complementary parts, inOut will combine debates among professionals from established and incumbent companies, start-ups, academics, students and live experiences on the city territory including the citizens of Rennes and its surroundings. More than just a recurrent annual event, inOut is set to continue throughout the year as a unique incubator on a human scale, where new mobilities are invented [IN]door and are tested [OUT]doors with users in real time. It's a one-of-a-kind co-creation platform providing industrial partners, start-ups, incumbent and new mobility players the opportunity to invent new mobility services, to experiment and test new use cases and business models, in close proximity to and with the citizens. Through a series of controversial debates, the event invites professionals, academics and local authorities from all over the world to separate hype from reality and discuss enablers and potential blocking points of these new mobilities.

We have been strongly involved in the creation of InOut and Jean-Marie Bonnin is responsible of the "Expert Committee" of the event.

This autumn the work done to design the InOut concept provided the basis to build the answer of Rennes Metropole to the AMI "Territoire Innovant de Grande Ambition".

10. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] Z. Liouane, T. Lemlouma, P. Roose, F. Weis, M. Hassani. *An improved extreme learning machine model for the prediction of human scenarios in smart homes*, in "Applied Intelligence", September 2017 [*DOI :* 10.1007/s10489-017-1062-5], https://hal.inria.fr/hal-01678671

[2] S. Muller, C. Harpes, Y. Le Traon, S. Gombault, J.-M. Bonnin. *Efficiently computing the likelihoods of cyclically interdependent risk scenarios*, in "Computers and Security", January 2017, vol. 64, pp. 59 - 68 [*DOI :* 10.1016/j.cose.2016.09.008], https://hal.archives-ouvertes.fr/hal-01427488

International Conferences with Proceedings

[3] S. El Jaouhari, A. Bouabdallah, J.-M. Bonnin, T. Lemlouma. *Securing the Communications in a WoT/WebRTC-based Smart Healthcare Architecture*, in "MT4H 2017 : 2nd International Workshop on Mobile Technology for Healthcare", Exeter, United Kingdom, IEEE, June 2017, vol. I-SPAN-FCST-ISCC 2017, pp. 403 - 408 [*DOI :* 10.1109/ISPAN-FCST-ISCC.2017.70], https://hal.archives-ouvertes.fr/hal-01666280

[4] S. El Jaouhari, A. Bouabdallah, J.-M. BONNIN, T. LEMLOUMA. *Toward a Smart Health-care Architecture Using WebRTC and WoT*, in "WorldCIST 2017", Porto Santo Island, Madeira, Portugal, Á. Rocha, A. M. Correia, H. Adeli, L. P. Reis, S. Costanzo (editors), Recent Advances in Information Systems and Technologies, Springer, April 2017, vol. Advances in Intelligent Systems and Computing, n^{o} 571, pp. 531-540 [*DOI :* 10.1007/978-3-319-56541-5_54], https://hal.archives-ouvertes.fr/hal-01503434

Scientific Books (or Scientific Book chapters)

[5] S. El Jaouhari, A. Bouabdallah, J.-M. Bonnin. *Security issues of the web of things*, in "Managing the Web of Things : Linking the Real World to the Web", Elsevier, 2017, pp. 389 - 424 [*DOI :* 10.1016/B978-0-12-809764-9.00018-4], https://hal.archives-ouvertes.fr/hal-01511323

References in notes

[6] 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° PI 1998, Publications Internes de l'IRISA ISSN : 2102-6327, https://hal.inria.fr/hal-00864884