UMR IRISA

Activity Report 2018

Team CASA

Opportunistic Networking and Computing

D2 - NETWORKS, TELECOMMUNICATION AND SERVICES

1 Team composition

Faculty

Frédéric Guidec, Professor, UBS[1], head of the team
Yves Mahéo, Associate Professor (HDR), UBS
Nicolas Le Sommer, Associate Professor, UBS
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Frédéric Raimbault, Associate Professor, UBS
Lionel Touseau (ATER until August 2018, post-doc since September)

PhD students

Fadhlallah Baklouti, CDE UBS / C.G. Morbihan grant, since October 2014
Mathieu Bagot, LabEx CominLabs grant, since October 2015

[1]UBS : Université Bretagne Sud

2 Overall objectives

2.1 Overview

The research activity of team CASA aims at supporting communication and service provision in mobile networks that operate by exploiting transient radio contacts between mobile devices. Such networks are usually referred to as opportunistic networks in the literature[PPC06], although the terms delay-tolerant and disruption-tolerant networks (DTNs) are sometimes used instead. Indeed, according to Mota et al., delay/disruption-tolerant networks should actually be considered as a subset of opportunistic networks[MCM+14].

In an opportunistic network, the topology of the network can be modeled as a dynamic graph. This graph is usually not connected, as a consequence of the sparse distribution of mobile nodes, and because radio transmissions between these nodes can only be performed at short range.

In such conditions, mobility can be considered as an advantage as it makes it possible for messages to propagate network-wide, using mobile nodes as carriers that can move between remote fragments of the network. Each mobile node can thus store each message for a while, carry messages while moving around, and use any radio contact as an opportunity to forward messages to another node. This *store, carry and forward* principle is the foundation of opportunistic networking.

Part of our activity in team CASA consists in designing routing protocols for opportunistic networks, and implementing these protocols in communication middleware so they can be tested in real conditions. We also investigate how distributed applications can be designed so as to perform satisfactorily in such networks. Indeed, designing distributed applications that require network-wide communication and coordination in an opportunistic network is quite a challenge, when communication and coordination depend on unpredicted pairwise contacts between neighbor nodes. The term *Opportunistic Computing* has been introduced in the literature in order to refer to a new computing paradigm that relies exclusively on such pairwise contacts[CGMP10]. Team CASA strives to contribute to the development of this computing paradigm by designing methods, models, and middleware tools that make it easier for programmers to tackle the challenges presented by opportunistic networks.

2.2 Scientific foundations

2.2.1 Opportunistic networking

In the early 2000s the IETF initiated the DTN Research Group (DTNRG), whose charter was to define an architecture for both Delay- and Disruption-Tolerant Networks. This group was

[PPC06] L. PELUSI, A. PASSARELLA, M. CONTI, "Opportunistic Networking: Data Forwarding in Disconnected Mobile Ad Hoc Networks", *IEEE Communications Magazine 44*, 11, November 2006, p. 134–141.

[MCM+14] V. F. S. MOTA, F. D. CUNHA, D. F. MACEDO, J. M. S. NOGUEIRA, A. A. F. LOUREIRO, "Protocols, Mobility Models and Tools in Opportunistic Networks: A Survey", *Computer Communications 48*, July 2014, p. 5–19.

[CGMP10] M. CONTI, S. GIORDANO, M. MAY, A. PASSARELLA, "From Opportunistic Networks to Opportunistic Computing", *IEEE Communications Magazine 48*, 9, September 2010, p. 126–139.

concluded in April 2016. In the meantime it has defined the architecture requested by the IETF (in two versions), together with a bundling protocol (BP) specification[SB07], and several "profile" documents that contain descriptions of convergence layers intended to fit the needs of specialized networking environments (e.g., space, water, sensor networks).

The DTN2 architecture and the associated bundle protocol (BP) are often believed to constitute an all-purpose solution for any kind of challenged network lacking end-to-end connectivity. Moreover, the fact that the DTN Research Group has concluded its work in 2016 may be interpreted as an indication that no further research activity is required along that line. Yet several authors have observed that although the Bundle Protocol is perfectly suited for inter-planetary networking, other kinds of networks (e.g., vehicular networks, pocket-switched networks, and mobile wireless sensor networks) may as well rely on alternative, lighter solutions[WEH09,WHFE09,Voy12]. Mota et al. suggest that the term delay-tolerant network should be used only for networks that strictly adhere to the DTN2 architecture, and they propose that the term opportunistic network be used for any kind of challenged network that exploits transient radio contacts between mobile nodes[MCM+14].

Thus, although the activity around the DTN2 architecture is now discontinued, message routing in opportunistic networks is still a hot topic for many research teams, including team CASA. The team continuously designs and evaluates opportunistic routing protocols, exploring different kinds of forwarding algorithms (content-based epidemic forwarding, location-based routing, service-oriented routing, etc.). The latest results obtained along that line are presented in §3.

2.2.2 Opportunistic Computing

Opportunistic computing is an emerging paradigm that builds on the results of several research areas (including autonomic computing and social networking), moving forward from simple communication to develop a framework to enable collaborative computing tasks in networking environments where long disconnections and network partitions are the rule[CGMP10].

Service-oriented computing appears to be a well-suited model for ambient computing environments, including those involving opportunistic communication. Building applications by combining software services is now well mastered and supported by many techniques and tools, among which the most popular Web Services. Since this approach fosters decoupling between applicative entities, it should be ideally suited to accommodate the connectivity constraints observed in opportunistic networks. Yet, although several middleware solutions have

[SB07] K. Scott, S. Burleigh, "Bundle Protocol Specification", IETF RFC 5050, November 2007.

[WEH09] L. Wood, W. M. Eddy, P. Holliday, "A bundle of problems", *in: Aerospace conference, 2009 IEEE*, IEEE, p. 1–17, 2009.

[WHFE09] L. Wood, P. Holliday, D. Floreani, W. M. Eddy, "Sharing the Dream: the Consensual Hallucination Offered by the Bundle Protocol", *in: Internation Congress on Ultra Modern Telecommunication (ICUMT'09)*, IEEE, p. 1–2, 2009.

[Voy12] A. G. Voyiatzis, "A Survey of Delay- and Disruption-Tolerant Networking Applications", *Journal of Internet Engineering 5*, 1, June 2012, p. 331–344.

[MCM+14] V. F. S. Mota, F. D. Cunha, D. F. Macedo, J. M. S. Nogueira, A. A. F. Loureiro, "Protocols, Mobility Models and Tools in Opportunistic Networks: A Survey", *Computer Communications 48*, July 2014, p. 5–19.

[CGMP10] M. Conti, S. Giordano, M. May, A. Passarella, "From Opportunistic Networks to Opportunistic Computing", *IEEE Communications Magazine 48*, 9, September 2010, p. 126–139.

been proposed during the last decades to support service provision and invocation in mobile ad hoc networks (MANETs), they can only be used in connected networks. In opportunistic networks, the absence of network-wide end-to-end connectivity, and the transmissions delays induced by the store, carry, and forward model require that specific solutions be devised in order to support both service discovery and service invocation.

Beside service-oriented computing, other computing paradigms have also long proved useful for designing distributed applications. Group communication, publish-subscribe systems, message queues, tuple spaces, are thus abstractions or systems for which efficient implementations are available in software development kits. Yet most of these implementations have been realized for traditional, connected environments. They cannot operate satisfactorily in partially or intermittently connected environments, and must be completely revised in order to tolerate network partitions, transmission disruptions, or long transmission delays.

2.3 Application domains

The research work carried out in team CASA is focused on the design and the implementation of middleware support for applications targeting challenged networking environments. We are particularly interested in providing support for mobility and continuity of service, even in the absence of any stable communication infrastructure. This applies to multiple environments where adaptive and cooperative applications are required, but where cost or technical constraints preclude the deployment of stable computing and communication resources. Possible application domains are:

- Collaborative computing in crisis operation fields (e.g., military operations, disaster relief situations);
- Sensor and actuator networking, as part of the Internet of Things (e.g., environment monitoring, crowd sensing, robot/drone control);
- Automotive computing (e.g., vehicle-to-vehicle and vehicle-to-roadside communication);
- Home automation (e.g., smart home applications);
- Nomadic computing (e.g., coordination and data sharing in rural or developing areas);
- Crowd-sensing (e.g., distributed content production and sharing);
- Personal communication systems (e.g., group communication, social interactions);
- Mobile health (e.g., ambulatory patient monitoring).

To date the activities conducted in team CASA already cover several of these application domains. For example, the problem of controlling mobile robots remotely through intermittent transmission links has recently been considered in project ASAWoO[2]. Data sharing among people during social events such as cultural or sports events has likewise been addressed in project C3PO[3]. Monitoring the health status of people wearing biometric sensors during their

[2] `https://projet.liris.cnrs.fr/asawoo`
[3] `http://laboratoirehubertcurien.fr/c3po-anr`

daily activities is addressed in project SHERPAM (see §5.1.1); and using Web browsers to support opportunistic distributed applications is addressed in project O'Browser (see §5.1.2).

Most of the middleware systems developed in team CASA over the recent years can also be considered as enablers for the above-mentioned application domains. Please refer to the team's Web site[4] for further information about these systems.

3 Scientific achievements

3.1 Opportunistic computing with Web browsers

Participants: F. Guidec, Y. Mahéo, P. Launay.

Web browsers have turned into the most widely deployed execution environments in the world. Empowered with browser-to-browser communication capabilities, they can be seen as nodes of a wide range of peer-to-peer applications. In the framework of ANR project O'Browser (see §5.1.2), team CASA studies how browser-to-browser communication can be achieved when browsers run on mobile devices in an infrastructure-less context, hence relying on opportunistic networking to cope with the lack of connectivity. The use of a content-based opportunistic middleware system such as DoDWAN (see §4.6) has been identified as a good approach for this purpose (techniques such as WebRTC are not an option, due to the need of stable servers to initiate communication). As a proof-of-concept, a simple user application has been developed in Javascript. This application can run in a browser on any smartphone and interacts with an instance of DoDWAN hosted in a battery-powered Raspberry Pi. This kind of architecture will allow the distributed sofware tools that are to be developed in project O'Browser to be experimented in real conditions.

Besides, further development of DoDWAN has aimed at interfacing this middleware system with the LEPTON emulation platform (see §4.4), which makes it possible to run experiments involving hundreds of instances of DoDWAN on a simple laptop or dekstop workstation.

3.2 Disruption-Tolerant Mobile Health Monitoring

Participants: M. Bagot (PhD), P. Launay, F. Guidec.

The concept of Wireless Biomedical Sensor Network (WBSN) opens up new opportunities for biomedical monitoring, such as the long-term, continuous monitoring of patients in a clinical environment or at home. In a typical deployment scenario, one or several wireless sensors are attached to a patient, and wireless transmission is used to forward data to a remote site (such as a physician's desktop computer or a hospital's monitoring center), usually through a local gateway. In traditional mHealth (Mobile Health) scenarios, it is commonly assumed that the transmission link between sensor and monitoring site is continuously available and reliable: the general assumption is thus that frequent, long-term disruptions should never occur while a patient's health status is being monitored. Such an assumption holds when a patient does not move much around the gateway, as is the case in a hospital environment or at home. Yet

[4] https://www-casa.irisa.fr/software

there are other circumstances when the connectivity between sensor and base station can be seriously disrupted by the patient's mobility. In team CASA we investigate the possibility of using opportunistic networking as a means to tolerate transmission disruptions between sensors worn by highly mobile people in outdoor conditions, and a remote monitoring center. A flexible architecture for disruption-tolerant mobile health monitoring has been designed along this line, and an Android application has been developed as part of this architecture (see §4.3 and §5.1.1) [2, 3].

A clinical trial using the SHERPAM system is now under way. This trial started on November 2018 and should continue until June 2019. During that interval, the health of about 40 volunteers will be monitored during their daily activities.

3.3 Composition of opportunistic services

Participants: F. Baklouti (PhD), N. Le Sommer, Y. Mahéo.

The Internet of Things is characterized by the variety of devices susceptible to provide services. Besides, these services are likely to be basic functionalities for collecting, generating or processing data, due to the limitation of the devices themselves or that of the network they are connected to. Yet, the end-user is preferably provided with a rich application, that actually combines a set of basic functionalities. We study the dynamic composition of services in the context of an opportunistic IoT, that is to say when the devices form an opportunistic network. The absence of end-to-end connectivity is a challenge for the composition process and state-of-the-art techniques are mostly inapplicable. These techniques are generally designed for an Internet-like context and are likely to cause prohibitive delays because they implement entire conversations between devices that induce several transmissions across the whole network. We have proposed a middleware system that supports the discovery, the selection, the invocation and the composition of services in opportunistic networks. A composition request issued by a node that has discovered a service is implemented according to one of two strategies, based respectively on choreography and orchestration. These strategies can be parameterized with a utility function that makes it possible to estimate the delay and the success of a transmission between a service client and a service provider, and to select the provider according to these values. A prototype middleware has been developed on top of the C3PO communication library (see §4.2) and a comparative study of the two strategies has been conducted on several deployment scenarios [4, 5].

Two additional mechanisms have been implemented in the prototype in order to improve the composition (i.e. to reduce the composition time and to increase the success ration of the compositions). The first mechanism is a distributed cache that makes it possible to share partial and completed compositions between devices in order to avoid to trigger the same compositions several times. Besides providing composition results quickly, this mechanism also allows to reduce the energy consumption of devices, since they do not compute compositions if results for them are available. The second mechanism consists in triggering composition requests proactively, based on the interest profiles of the users and on the services that have discovered in the network. This proactive mechanism also participates in the reduction of the composition time, and thus to the quality of service/experience felt by users.

3.4 Emulation platform for opportunistic networking

Participants: F. Guidec, Y. Mahéo, P. Launay.

Mobile routing protocols are usually tested using discrete-event simulators. Moreover the code thus tested is often pseudo-code, which is significantly simpler than the real code that should be deployed on real mobile devices. For these reasons simulation results should only be considered as qualitative assessments[KM07], and any system that is first tested with a simulator should later also be tested in real conditions. This requires deploying testbeds, possibly at a large scale. Undoubtedly running experiments in a testbed offers the greatest degree of realism (since everything is running "for real"), but deploying and managing hardware and software in a testbed is a costly and time-consuming endeavor.

Emulation is an approach that fits between simulation and testbeds, as it involves real elements used along with simulators. Several emulation systems for mobile ad hoc networks have been proposed during the last decade, and some of these systems can be used to simulate opportunistic networks. Yet most of these systems (e.g., TUNIE, EmuStack, MoViT, HYDRA, TWINE) are actually testbeds extended with node virtualization. For the developer of an opportunistic networking protocol or algorithm, gaining access to one of these testbeds or deploying an equivalent system for testing his/her code is hardly an option, at least not for early experiments while the code is still under development. A lighter solution is needed, even if using this solution implies trading off a bit of transparency and accuracy against availability and ease of use.

Team CASA has initiated the development of a lightweight emulation platform for opportunistic networking (see §4.4 for details). Unlike other existing network emulators, this platform is easily deployable on a standard laptop or workstation (or on a cluster of workstations when computing power is required), without requiring any virtualization technology, nor any particular privilege for the user.

3.5 Evaluation and comparison of opportunistic networking

Participants: P. Launay, Y. Mahéo, F. Guidec.

The developers of routing protocols usually rely on simulators, more rarely on emulators or "real world" experiments, in order to check and evaluate the algorithms and protocols they develop. However, exploiting the results produced by such experiments is a tedious task, and comparing these results with those produced by other researchers is even harder, because of the lack of relevant and well-established metrics and standardized data formats. Team CASA aims to develop a unified evaluation platform to facilitate the evaluation and comparison of experiment results pertaining to opportunistic networking and computing. To achieve this goal, the team has started working along several directions:

- Identification and comparison of several ways to characterize mobility and contacts scenarios, based on various dynamic graphs metrics, such as network diameter, density,

[KM07] W. Kiess, M. Mauve, "A Survey on Real-world Implementations of Mobile Ad-hoc Networks", *Ad Hoc Networks 5*, 3, April 2007, p. 324–339.

temporal distances, nodes centrality, etc. Several contact scenarios have been analyzed using these metrics.

- Analysis of the performances of routing algorithms according to the characteristics of contacts and application scenarios.
- Computation of "ideal" measures from contact and application scenarios (e.g., temporal distances between nodes), and comparison of these ideal measures with actual results (e.g., message delivery delays), using the same metrics.
- Definition and comparison of different ways to present and compare results graphically.
- Definition of event-based file formats to represent contact and mobility scenarios (based on the DGS file format used in the GraphStream[5] platform) on the one hand, and application scenarios and experiments output files on the other hand.
- Development of conversion algorithms to transform contact and mobility datasets from one format to another.
- Conversion and analysis of datasets extracted from the CRAWDAD[6] database.

4 Software development

4.1 Platform ASAWoO

In the context of project ASAWoO[7], which was concluded in 2017, team CASA has participated in the design and development of a middleware platform for the Web of Things. Our main contributions consisted in designing and implementing:

- the avatar runtime container architecture;
- the functionality and WoT modules in charge of instantiating and publishing functionalities of avatars (i.e. virtual representations of devices);
- the WoT application manager which enables applications deployment based on available functionalities and contextual information;
- the opportunistic communication adaptation layer.

The ASAWoO platform [15, 16] also integrates a reasoning module and a context adaptation module that make it possible for avatars to reason on the semantic descriptions of their capabilities and their functionalities, and thus help them to infer new high-level and complex functionalities that better match the users' needs than the low-level capabilities, and that are suited to their running context.

The source code of the ASAWoO platform is distributed under the CeCILL license (compatible with GNU GPLv2). It is available in a GIT repository[8], together with its documentation for users and developers.

[5] `http://graphstream-project.org`
[6] `https://www.crawdad.org`
[7] `https://projet.liris.cnrs.fr/asawoo`
[8] `https://gitlab.com/asawoo`

4.2 C3PO development

C3PO (*Collaborative Creation of Contents and Publishing using Opportunistic networks*) is a middleware platform that has been developed in project C3PO[9], which was concluded in 2017 [10]. This platform implements opportunistic communication techniques relying on the concepts of micronets and macronets [12]. It makes it possible to create mobile ad hoc networks using off-the-shelves mobile devices, as well as hybrid networks composed of both infrastructure and mobile parts. To do so, it supports various communication modes and wireless technologies (e.g. Bluetooth, Wi-Fi legacy mode, Wi-Fi ad hoc mode, Wi-Fi Direct, 3G/4G, XBee). This platform provides two distinct application-level communication paradigms: a topic-based publish/subscribe model, and a channel-based send/receive model.

The topic-based publish/subscribe communication model makes it possible to develop applications that can publish multimedia contents on specific topics, and subscribe in order to receive the contents related to given topics. The model implemented in the C3PO framework relies on a purely peer-to-peer decentralized approach. Topic names are assumed to be already known by the application, as a given topic is generally pre-defined or handled by a single application module that performs both production and consumption. The subscription and the publication are local to each device. Thanks to the store-carry-and-forward principle, contents published in a topic by publishers are disseminated opportunistically in the communication network by mobile devices, being either devices hosting subscribers for this topic or ordinary intermediate devices, and are thus delivered to the topic subscribers.

The point-to-point communication paradigm using the concept of channel is intended for applications that allow users to communicate with each others by sending messages addressed to specific recipients. In the framework, a channel between two devices is identified by the addresses of the devices and a channel ID. Messages sent through a channel are opportunistically forwarded by intermediate devices towards their destination according to one of the message forwarding strategies implemented in the framework. Primitives similar to the ones used for Java sockets are available to the programmer (open, accept, receive...). Asynchronous receiving is also possible by registering a message listener associated with a channel.

C3PO-based mobile Android applications dedicated to sport events have been developed in project C3PO. Wi-Fi access points embedding this platform have also been built in this project. These access points have been used during experiments in order to help network formation and to collect data and traces generated by users for analytical purposes. These mobile applications and these access points have been tested in real conditions during several running events, and especially during the semi-marathon of Beaune, where more than 1200 people used the C3PO-based mobile application dedicated to that event to share multimedia contents, to follow the run and to obtain the results of the semi-marathon.

The first version of this middleware platform has been registered with the French Agence pour la Protection des Programmes (IDDN.FR.001.100015.000.S.C.2018.000.10000).

4.3 SHERPAM health monitoring system

A software system is under development in the framework of project SHERPAM (see §5.1.1). This system shall make it possible to monitor continuously the health status of fragile people

[9] `http://laboratoirehubertcurien.fr/c3po-anr`

during their daily activities, supporting all stages of data acquisition, transmission, and processing.

Sensors worn by a subject are used to acquire data pertaining to the subject's status (acceleration, gyroscope, heart rate or full-featured ECG, temperature, location, etc.). Data streams produced by these sensors are gathered by a portable "gateway", which is also worn by the subject. This gateway pre-processes data, so they can be transferred to a remote site for storage and analysis. The sensors and the gateway together constitute a Body Area Network (BAN), and transmissions in this BAN rely on Bluetooth links (including Bluetooth Low Energy). Support for other transmission technologies (e.g., ANT+) may be included later in the system.

Before transferring data to a remote site, the gateway can pre-process these data in order to reduce the amount of data to be transferred, or in order to detect interesting patterns in these data. In the latter case, the subject can be warned directly by audible or visual notifications.

In the framework of project SHERPAM, the gateway is typically an Android smartphone running a dedicated application The first version of this Android application has been registered with the French Agence pour la Protection des Programmes (IDDN.FR.001.540019.000.S.P.2015.000.31230). Further details are available on the project's Web site[10].

4.4 LEPTON

LEPTON *(Lightweight Emulation Plaftorm for Opportunistic Networking)* is an emulation platform that is meant to facilitate the evaluation of opportunistic networking systems. It allows the developers of opportunistic networking software (i.e., middleware and/or applications) to run their software systems with simulated mobility [1].

Unlike other emulation platforms, LEPTON does not require exotic networking equipment, and it does not even require deploying virtual machines on one or several hosts. A simple laptop or desktop workstation running Linux can easily support emulation-based experiments involving up to a couple hundred nodes, and larger experiments can be run on any cluster of Linux machines.

Being an emulator rather than a simulator, LEPTON is meant to drive the communication between full-featured instances of an opportunistic networking system (a.k.a. OppNet system), each instance determining the behavior of one system node (SN) during the simulation. To date only a few existing OppNet systems are openly distributed, but LEPTON can already operate with several of these systems, and others should be included over time:

- DoDWAN: an OppNet system that supports content-based communication in partially or intermittently connected environments;
- IBRDTN: an OppNet system that implements the Bundle Protocol, as defined in RFC 5050.
- aDTN (a.k.a. Active DTN): an OppNet system that also implements the Bundle Protocol, and that uses bundles as a means to propagate routing software code all over the network.

[10] `https://sherpam.cominlabs.u-bretagneloire.fr/results/prototype`

LEPTON is distributed under the GNU General Public License (GPL)[11].

4.5 Evaluation platform for opportunistic networking and computing

MUON *(Miscellaneous Utilities for Opportunistic Networking)* is a platform that is being developed by team CASA in order to provide online access to conversion, analysis and presentation tools relying on the data formats and metrics defined in our team, and thus provide a unified framework for the evaluation and comparison of opportunistic routing protocols. Analysis tools have been developed to calculate and present metrics to characterize mobility and contact scenarios, and to evaluate algorithms performances. Conversion tools have been developed to transform, filter and sanitize datasets. These tools are made accessible through a Web front-end that makes it possible for a user to upload mobility, contacts and experiment log files, run conversion and analysis tools, and display and download results.

The development of the MUON platform is still under way, but this platform should be online and available for users in the near future.

4.6 DoDWAN

DoDWAN is a flexible Java-based middleware platform that has been developed in team CASA in order to support content-based, disruption-tolerant communication in opportunistic networks. It is distributed under the GNU General Public License (GPL)[12].

In content-based networking, information flows towards interested receivers rather than towards specifically set destinations. This approach notably fits the needs of applications and services dedicated to information sharing or event distribution.

A suite of applications suitable for disconnected MANETs has been developed on top of the DoDWAN middleware system. This suite is called DoDWAN-Apps, and it is available for laptops and netbooks running Linux or Windows, as well as for Android smartphones. DoDWAN-Apps is meant to be a fully-functional demonstrator of the concept of opportunistic ad hoc networking. With a mobile device running DoDWAN-Apps a user can for example locate other users in the neighborhood and exchange text messages, voice messages, or files with any other user or group of users.

DoDWAN and DoDWAN-Apps have been tested and demonstrated on several occasions during the past years (communications on the battlefield, while trekking in remote areas, etc.). Recently, an experiment involving volunteers roaming our university campus has been performed, and its results are presented on the team's Web site[13].

DoDWAN is registered with the French Agence pour la Protection des Programmes (IDDN.FR.001.170036.000.S.P.2013.000.10200). Recent developments concerning this platform are discussed in §3.1.

[11] http://www.irisa.fr/casa/lepton
[12] http://www.irisa.fr/casa/dodwan
[13] https://casa-irisa.univ-ubs.fr/dodwan/field_expe_2018_01.html

5 Contracts and collaborations

5.1 National Initiatives

5.1.1 Project SHERPAM

- Participants: M. Bagot (PhD), P. Launay, F. Guidec
- Project type : LabEx CominLabs
- Dates : 2014-2019
- Partners : LTSI (Rennes 1), M2S (Rennes 2, ENS Rennes), LAUREPS (Rennes 2), CIC-IT 804-CHU Rennes

The objective of project SHERPAM *(Sensors for HEalth Recording and Physical Activity Monitoring)* is to design, implement, and validate experimentally a system based on biophysical sensors to monitor people during their daily life. Two application domains are considered specifically in this project: the evaluation of the functional limitations of arteriopathic patients, and the recognition and quantization of physical activity for a given population.

5.1.2 Project O'Browser

- Participants : F. Guidec, Y. Mahéo, P. Launay
- Project type : ANR, generic programme
- Dates : 2017-2020
- Partners : teams LINA/GDD (Nantes), IRISA/ASAP (Rennes), and Orange Labs Research (Lannion)

The objective of project O'Browser *(Opportunistic Fog Computing with Browsers)* is to propose a novel programming framework, whereas distributed applications can be deployed on Web browsers, and operate based on browser-to-browser communication, without relying on a cloud or a central authority. When the browsers involved run on mobile devices, opportunistic networking will be used as a means to cope with connectivity disruptions.

5.2 Collaborations

A collaboration has been initiated between team CASA and team SeNDA (Universitat Autònoma de Barcelona) in order to work jointly on the evaluation of the emulation platform LEPTON (see §4.4). Experiments have been conducted by both teams using this platform, and the results of these experiments have been published in [1].

6 Dissemination

6.1 Promoting scientific activities

6.1.1 Journal

Reviewer - Reviewing Activities

- F. Guidec
  - Reviewer for the Ad Hoc Networks journal (Elsevier)

6.2 Teaching, supervision

6.2.1 Teaching

- F. Guidec
  - Master 1: “Technological watch”, 20 h
  - Master 1: “Network administration”, 38 h
  - Master 2: “Wireless networking technologies”, 52 h
  - Master 2: “Innovating systems and networks”, 20 h
  - Master 2: “Internet of Things”, 26 h
- Y. Mahéo
  - Master 1: “Introduction to distributed systems”, 20 h
  - Master 1: “Technological watch”, 16 h
  - Master 1: “Tutored projects”, 8 h
  - Master 1: “System administration”, 30 h
  - Master 2: “Innovating systems and networks”, 20 h
  - Master 2: “Distributed algorithms”, 8 h
  - Master 2: “Distributed middleware”, 20 h
- P. Launay
  - Master 1: ”Distributed systems: Java Networking”, 12 h
  - Master 2: “Network support for multimedia applications: WebRTC”, 8 h
  - ENSIbs[14] 2: “Advanced Object Programming“, 36 h
  - ENSIbs 2: “Computer Networks“, 30 h
  - ENSIbs 2: “Middleware for distributed computing“, 38 h
  - ENSIbs 3: “Graduation projects supervision“
- F. Raimbault

[14]ENSIbs: Engineering school.

  - Master 1: "Introduction to Distributed Systems", 12 h
  - Master 1: "Tutored Projects", 12 h
  - Master 2: "Distributed Programming", 40 h
  - Master 2: "High Performance Computing for the Big Data", 32 h

- N. Le Sommer
  - Master 2: “Development of mobile applications”, 20 h
  - Master 1: “Project management tools”, 4 h

6.2.2 Supervision

- F. Baklouti, “Definition of an adaptive service-oriented shared space for spontaneous ephemeral social networks”, supervised by Y. Mahéo and N. Le Sommer, PhD in progress
- M. Bagot, “Adaptive disruption-tolerant data transmission for the biomedical monitoring of mobile subjects”, supervised by F. Guidec and P. Launay, PhD in progress

6.2.3 Juries

- F. Guidec : president of the PhD jury of M. Riyami Bouchaid (“Analyse des effets des TIC sur l’enseignement supérieur au Maroc dans un contexte de formation en collaboration avec une université française”), Université Bretagne Sud, July 2018.

7 Bibliography

Major publications by the team in recent years

[1] M. AUZIAS, *Programming Support for a Delay-Tolerant Web of Things*, PhD Thesis, Université Bretagne Sud / Université Bretagne Loire, October 2017.

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