Summary of the project TEPN

Toward Energy Proportional Networks
(2013-2018)

Introduction

Wireless networks have been designed for delivering maximal data rate at peak usage resulting in high power consumption from network devices (e.g., base stations (BS), core network) with little or no dependency on the traffic load, as illustrated in Figure 1 below. However, the network is not always running at its peak and the studies in the TEPN project were focused on techniques allowing the network energy consumption to be proportional to its load: near zero power consumption when there is little or no traffic, and a proportional increase of power w.r.t. the load. We have first identified the elements the consume most of the power. These include the Power Amplifier (PA), cooling, and the BS. We have proposed solutions whose power consumption is indeed proportional to the load and that also reduce significantly the power consumption of the network. These solutions include signal processing for PA linearity, new energy-efficient waveforms, and strategies to turn on and off BSs.
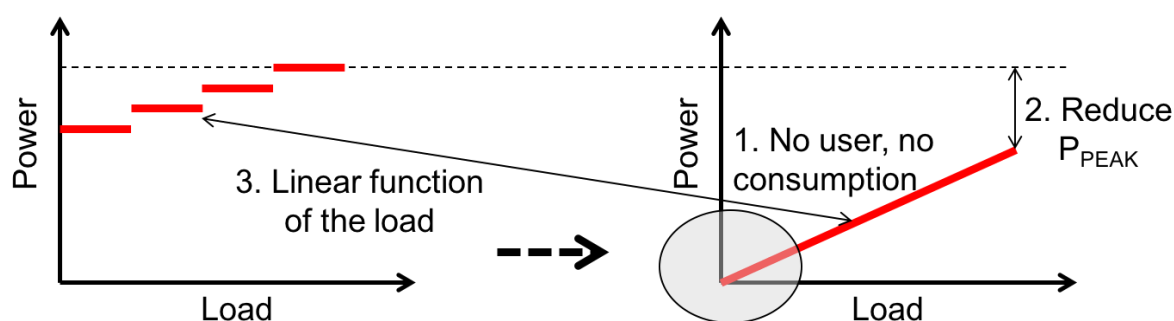

Figure 1: Objective of the project: render power consumption proportional to the load.

The project allowed to fund 6 PhDs students (+ 6 months of a seventh PhD student) and 1 research engineer.

Organization and obstacles

The project was constructed around 6 PhDs co-supervised by researchers from at least two different teams as summarized in Fig. 2. If from the point of view of research teams

interaction this structure has been a success, we may regret a lack of cooperation between the PhD students themselves, with no joint publications between PhD students for instance. However, we think that this is mainly due to the fact that dissertations last for around three years hindering collaborations between PhD students who have often started at different times and who need to concentrate on redacting their dissertation in the final months of their studies. Following the mid-term evaluation, we particularly worked on an assessment of the hypothesis of work and on having a common definition of the energy consumption. We also defined common metrics and scenarios for performance evaluation. Note that several discussions and meetings were set up between PhD students but did not give rise to publications for example.
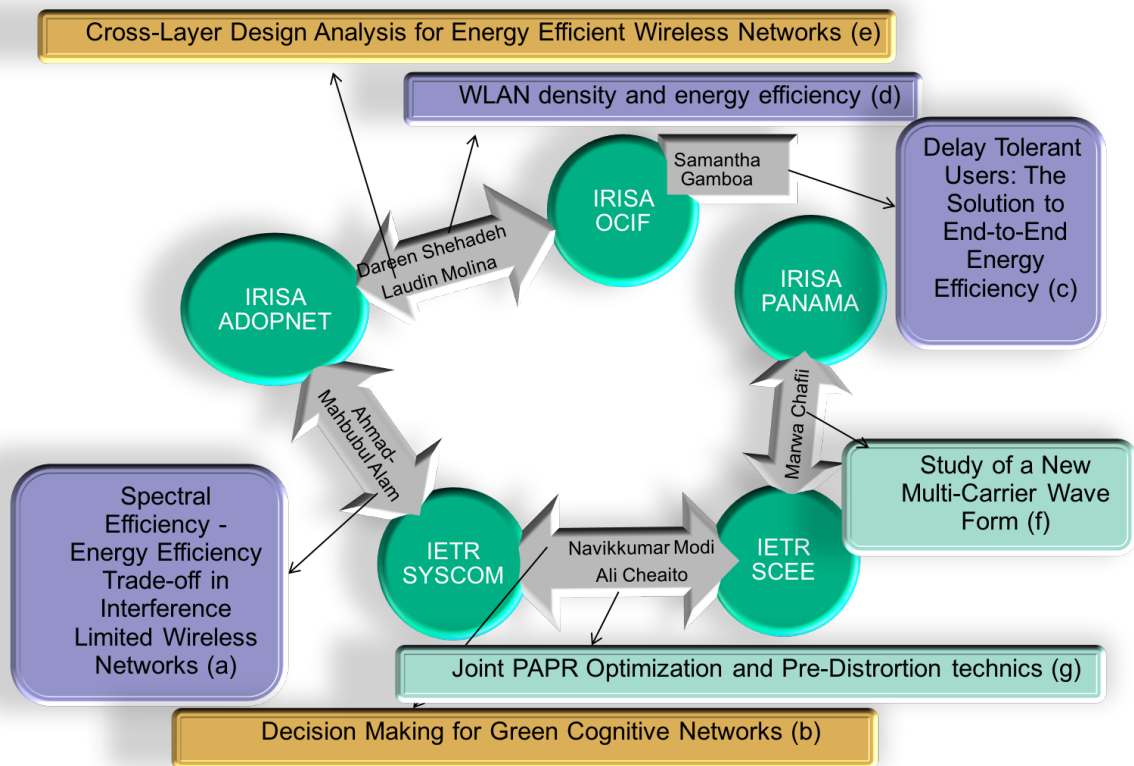

Figure 2: Project organization and research teams' interactions

No significant deviation was observed compared to the initial objectives, except the delays in starting the thesis (due to difficulties to find good candidates).

Scientific contributions

There was and there is still a huge need for developing sustainable information technologies that justified the European project FP7 EARTH that investigated the energy efficiency of mobile communications. Given the different scale of funding and resources of the EARTH project, the approach of TEPN -rather than competing with EARTH- was to tackle the problem under a cognitive angle in its largest sense, i.e., to add advanced processing in the network in order to save energy as much as possible.

2

All the work done in this project has the following equation as baseline

$$\underbrace{P_{\text{IN}}}_{\text{power to run BS}} = \overbrace{N_{\text{TRX}}\,(P_0}^{\substack{\text{systemic approaches}\\ \text{thesis a, b, c, d, e}}} + \underbrace{\Delta_p P_{\text{out}})}_{\substack{\text{signal processing}\\ \text{thesis a, f, g}}}$$

where N_{TRX} is the number of RF chains, P_0 is the power consumption independent from the load, P_{out} is the power radiated by antennas and Δ_p is the potentially varying slope according to the use of PA. The most significant contributions of this project allowed to optimize these terms in order to reduce the energy consumption of the network.

The first term in the right hand side of the equation above is due to the static power consumption of a BS and can be minimized by switching on, off or asleep some BS depending on the load of the network. This issue has been covered by the PhDs of Ahmad Mahbubul Alam (a), Navikkumar Modi (b), Samantha Gamboa (c), Dareen Shehadeh (d) and Laudin Molina (e). In particular, we studied how the energy efficiency - spectral efficiency (EE-SE) tradeoff behaves in a large scale network and if we can get insights from an engineering perspective. We proposed an analytical expression of EE-SE tradeoff based on Poisson-point processes and large random matrix theory. We found that there exists an optimal transmission power and an optimal number of BS antennas depending on BS and user density ratios that maximises both EE and SE. Due to the combinatorial nature of selecting which BS will stay ON and which one will be switched OFF, we used a Markovian decision process (MDP) with a restless multi-armed bandit strategy. The reinforcement learning approach proposed has been coupled to a transfer learning strategy, and we reached 5% difference from the optimal configuration in terms of EE (during night time, i.e., when there are many possible strategies). In order to study the dynamicity of the system, we introduced a possible delay for users before they are served. Our numerical evaluation, ns-3 simulation, and experimentation in city downtowns showed up to 78% of power reduction for an offered load of 7 erlangs, and up to 45% and 17% for 10 and 14 erlangs respectively. In the experimentation, we also evaluated that only 5-10% of the BS are needed to maintain the network coverage (in case of low traffic demand). More specifically, we evaluated at 30 percentage points the amount of possible additional power reductions when users are put to sleep in period of transition between BS states.

The second term in the right hand side of the equation above is due to non linearities of PA, among other things. Ali Cheaito (PhD thesis (g)) and Marwa Chafii (PhD thesis (f)) covered the Peak to Average Power Ratio (PAPR) issue with the objective to increase the PA efficiency and reduce the power consumption. We proposed closed form expressions to predict the Error Vector Magnitude value of a transmission and provided new analytical tools for the overall optimization of transmitters. Only upper-bounds or approximated expressions were available in the literature, which did not bring sufficient insight into the performance and

interactions between the various modules of transmitters. The new analytic forms derived during the project allow for the elaboration of a complete set of analytic laws that are expected to help designing and properly setting the different modules of a transmitter among which PAPR reduction methods, predistortion function and various PA models. The provided results show how it is possible to play with many degrees of freedom, address some performance/efficiency/complexity trade-off and evaluate their impact on power consumption.

Taking a different approach, we also worked on the PAPR derivation itself where it has been proved that the PAPR depends on this modulation structure. Moreover, the behavior of the PAPR regarding the modulation waveforms was analysed and the PAPR reduction problem was formulated as an optimization problem. Furthermore, a necessary condition for designing waveforms with better PAPR than OFDM has been derived. This necessary condition is particularly satisfied by a wavelet basis. Finally, two new adaptive waveforms were proposed, allowing significant gain in terms of PAPR, while keeping the advantages of multicarrier modulations : the first one being based on wavelet packet and the second one on the Fourier Transform.

For more in-depth details, interested readers can refer to the publications issued from this work, or the TEPN web site (https://tepn.cominlabs.u-bretagneloire.fr/). The scientific production of the project has reached a very high level in terms of quantity and quality (please refer to the table below).

Impact and Valorizations

TEPN was a successful project with 6 PhD who defended their thesis and one that is scheduled in June 2018. We count 57 publications in total and 2 patents. See Table 1 for more details.

The TEPN project supported strategic research for the laboratories involved in Cominlabs. The work initiated in the PhD of A. M. Alam on theoretical performance of randomly deployed network has opened new doors to be investigated and will be pursued by two PhDs dealing with variable traffic flows and correlation between stochastic processes and their impact on achievable performance. In particular, resource allocation has not been considered yet because it requires to deal with dependency between point processes, e.g. users and BS.

We were also selected by the Cominlabs committee to extend the work on the new waveform proposal to decrease the PAPR (described in one of the TEPN patent). In this accepted project, we will implement the proposed solution on a USRP platform. This work should start in 2018 for 18 months.

The work on real time monitoring in downtown and performance study we did in TEPN become a sustainable activity in the different teams involved. In 2016, we initiated new industrial contracts with Société Grand Paris on this very hot topic, and we are using the tools in many student projects and teaching activities.

We can also mention that one of the PhD student (Laudin Molina) is following the EIT Digital School for Innovation and entreprenariat. In this context, he had to work on business model and he visited a center of research during his PhD.

Indicators

	2013	2014	2015	2016	2017	2018	Total
Best paper award				2			2
Patents					1	1	2
Invited professor		1[1]					1
PhD Mobility		1	2	2	1		6
Defended PhD			1[2]	1	4	1	7
International journals	4	1	2	3	9	1	20
International Conferences		4	9	10	5		28
National Conferences			3	3	3		9

(1) Honggang Zhang
(2) Samantha Gamboa was partially funded by TEPN

Table 1: indicators for the TEPN project. Details are given in annex.

Conclusions and perspectives

The TEPN project was ambitious and put together different teams working on different layers of a communication framework. The approach we followed was interesting in the sense that we considered a systemic approach; instead of focusing on a single part of a system, we covered the full system and identified the key issues to provide energy efficiency. Throughout the 6 PhD thesis we supervised, we used different tools (modeling, analytical evaluation, experiment, simulation) and this also contributed to the success of the project. We covered many different approaches and were able to make significant contributions in different domains.

The initiated researches are still ongoing. Crowd sourcing and wireless network characterization are getting more and more interest from the community, the switching ON/OFF methods are now well accepted by the industrial and additional methods are investigated, such as the usage of renewable energy. PAPR reduction techniques also open several research possibilities, and the next 18 months will make the proposal goes to the next step, by showing if an implementation is possible.

ANNEX 1: Details of the indicators

Marwa Chafii applied to "prix de thèse Signal Image Vision 2018", but the selection process has not been issued yet.

Awards

Best Paper Award - Ali Cheaito, Matthieu Crussière, Jean-François Hélard, Yves Louët, Energy-Efficiency Optimization of the High Power Amplifier for Multicarrier Systems: Analytical EVM Derivation, IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS 2016), San Francisco, CA, 2016

Best Paper Award - Marwa Chafii, Jacques Palicot, Rémi Gribonval, La modulation en ondelettes: une modulation alternative à faible consommation d'énergie URSI France, Energy and Radio Science CentraleSupélec, Rennes, 2016

PhD program

Laudin Molina is following the EIT Doctoral School for innovation and entrepreneurship, from 2015 to 2018, to transfer his research from the lab to the marketplace.

Mobility

- Marwa Chaffi, Visiting the Chair of Wireless Communications, Poznan University of Technology, Poland. The main technical focus: "Time Frequency Localization analysis for different orthogonal transforms" Collaboration with: Dr. Adrian Kliks, June-July 2014
- Marwa Chafii, Visiting the Department of Electronics, University of York, United Kingdom. The main technical focus: "Study of the performance of the wavelet modulation: PAPR, spectral efficiency, and bit error rate for different channels" June-July 2015
- Marwa Chafii, Visiting the Department of Electrical and Computer Engineering, Communication Theory Laboratory, Yokohama National University, Japan. The main technical focus: "Study of the trade-off: Frequency Localization of the carriers and the PAPR", Collaboration with: Prof. Hideki Ochiai, July-August 2015
- Marwa Chafii, Research visit to the Department of Engineering Science - Oxford University, United Kingdom. "Performance Analysis of non-orthogonal multi-tone FSK modulation schemes.", Collaboration with: Prof. Alister G. Burr, June-August 2016
- Laudin Molina, Research visit to IMDEA Networks Institute, techniques to measure and predict the quality of wireless networks collaboration with Dr. Vincenzo MANCUSO, September – December 2017
- Laudin Molina, Research visit to Internship at iNETS, University of Aachen, Passive techniques to classify of the WiFi link quality, September – December 2016

PhD students

#	PhD student	Supervisors	Team	Subject	Def.	Current position
a	Ahmad Mahbubul Alam	Jean-Yves Baudais, Philippe Mary, Xavier Lagrange	SYSCOM, ADOPNET	Energy efficiency-spectral tradeoff in interference limited wireless networks	Mar. 2017	Post-doctoral researcher at Orange Labs, Paris
b	Navikkumar Modi	Christophe Moy, Philippe Mary	SYSCOM, SCEE	Machine Learning and Statistical Decision Making for Green Radio	May 2017	Research engineer at Skyline, Belgium
c	Samantha Gamboa	Alexander Pelov, Nicolas Montavont	OCIF	Delay Tolerant Users, a solution to end-to-end energy efficiency	Jun. 2015	
d	Dareen Shehadeh	Nicolas Montavont, Alberto Blanc	OCIF, ADOPNET	Dynamic Network Adaptation for Energy Saving	Dec. 2017	
e	Laudin Molina	Alberto Blanc, Nicolas Montavont	OCIF, ADOPNET	Non intrusive strategie to characterize IEEE 802.11 Networkz	May 2018	
f	Marwa Chafii	Jacques Palicot, Rémi Gribonval	SCEE, PANAMA	Study of a New Multi-Carrier Waveform	Oct. 2016	Research fellow, chair Vodafon, University of Dresden
g	Ali Cheaito	Matthieu Crussière, Yves Louet, Jean-François Helard	SYSCOM, SCEE	Analytical analysis of in-band and out-of-band distortions for	Mar. 2017	Post-doc., CentraleSupelec, Rennes

				multicarrier signals: impact of non-linear amplification, memory effect and predistortion		

Annex 2: Publications

Patents (2)

[1] Marwa Chafii, Jacques Palicot, Rémi Gribonval, **Dispositif de communication à modulation temps-fréquence adaptative** Patent FR3054091 - 2018-01-19 (BOPI 2018-03)

[2] Navikummar Modi, Christophe Moy, Philippe Mary, **Procédé d'accès opportuniste au spectre,** WO2017013088 - 2017-01-26

International Journals (20)

2018
[1] Marwa Chafii, Jacques Palicot, Rémi Gribonval, Faouzi Bader, **Adaptive Wavelet Packet Modulation,** *IEEE Transactions on Communications*, 2018

2017
[1] Ali Cheaito, Matthieu Crussière, Jean-François Hélard, and Yves Louët, **Quantifying the Memory Effects of Power Amplifiers: EVM Closed-Form Derivations of Multicarrier Signals,** *IEEE Wireless Communications Letters*, vol. 6, no. 1, Feb. 2017

[2] Navikkumar Modi, Philippe Mary, Christophe Moy, **QoS driven Channel Selection Algorithm for Cognitive Radio Network: Multi-User Multi-armed Bandit Approach,** *IEEE Transactions on Cognitive Communications and Networking*, vol. 3, no. 1, 2017.

[3] Mohamad Maaz, Philippe Mary, Maryline Hélard, **Energy Minimization in HARQ-I Relay-Assisted Networks with Delay-limited Users,** *IEEE Transactions on Vehicular Technology*, vol. 66, no. 8, 2017

[4] GAMBOA Samantha, PELOV Alexander, MAILLÉ Patrick, LAGRANGE Xavier, MONTAVONT Nicolas, Reducing the energy footprint of cellular networks with delay-tolerant users. IEEE systems journal, june 2017, vol. 11, n° 2, pp. 729-739

[5] A.M. Alam, P. Mary, J.Y. Baudais, X. Lagrange, **Asymptotic Analysis of Area Spectral Efficiency and Energy Efficiency in PPP Networks with SLNR Precoder**, *IEEE Transactions on Communications*, Vol. 65, no. 7, July 2017.

[6] Navikkumar Modi, Philippe Mary, Christophe Moy, **Efficient Learning in Stationary and Non-stationary OSA Scenario with QoS Guaranty,** *EAI Endorsed Transactions on Wireless Spectrum* : 2017

[7] Marwa Chafii, Jacques Palicot, Rémi Gribonval, **Wavelet modulation: An alternative modulation with low energy consumption,** *Comptes Rendus Physique*, vol. 18, no. 2, 2017

[8] L. Molina and T. Kerdoncuff and D. Shehadeh and N. Montavont and A. Blanc: **WMSP: Bringing the Wisdom of the Crowd to WiFi Networks,** *IEEE Transactions on Mobile Computing*, vol. 16, no. 12, 2017

[9] Marwa Chafii, Justin Coon, Dene Hedges. **DCT-OFDM with Index Modulation,** *IEEE Communications Letters*, vol. 21, no. 7, 2017.

2016

[1] Laura Melian-Gutiérrez, Navikkumar Modi, Christophe Moy, F. Bader, I. Perez-Alvarez, S. Zazo, **Hybrid UCB-HMM: A Machine Learning Strategy for Cognitive Radio in HF Band,** *IEEE Transactions on Cognitive Communications and Networking*, vol. 1, no. 3, 2016

[2] Ali Cheaito, Jean-François Hélard, Matthieu Crussière, Yves Louët, **EVM Derivation of Multicarrier Signals to Determine the Operating Point of the Power Amplifier Considering Clipping and Predistortion** *EURASIP Journal on Wireless Communications and Networking,* 2016, 2016:281

[3] Marwa Chafii, Jacques Palicot, Rémi Gribonval, Faouzi Bader, **A Necessary Condition for Waveforms with Better PAPR than OFDM,** *IEEE Transactions on Communications*, vol. 64, no. 8, 2016.

2015

[1] Sumit Jagdish Darak, Jacques Palicot, Honggang Zhang, Vinod Prasad, Christophe Moy, **Reconfigurable Filter Bank With Complete Control Over Subband Bandwidths for Multistandard Wireless Communication Receivers,** *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 23, no. 9, 2015

[2] Sumit Jagdish Darak, Sumedh Dhabu, Christophe Moy, Honggang Zhang, Jacques Palicot, A. Prasad Vinod: L**ow Complexity and Efficient Decentralized Spectrum Learning and Access With Tunable Bandwidth for Heterogeneous Cognitive Radio Networks,** *Digital Signal Processing*, vol. 37, no. 2, 2015

2014

[1] Marwa Chafii, Jacques Palicot, Rémi Gribonval. **Closed-form approximations of the peak-to-average power ratio distribution for multi-carrier modulation and their applications,** *EURASIP Journal on Advances in Signal Processing*, 2014, 2014 (1), pp.121.

2013

[1] Xuan Zhou, Zhifeng Zhao, Rongpeng Li, Yifan Zhou, Jacques Palicot, Honggang Zhang, **Human Mobility Patterns in Cellular Networks**, *IEEE Communications Letters*, Vol. 17, no. 9, 2013

[2] Xin Tao, Zhifeng Zhao, Rongpeng Li, Jacques Palicot, Honggang Zhang, **Downlink Interference Minimization in Cooperative Cognitive LTE-Femtocell Networks,** *EURASIP Journal on Wireless Communications and Networking* 2013, 2013:194.

[3] Jacques Palicot, Steve Mclaughlin, Honggang Zhang, Vince H Poor, **Editorial : Special issue on Green Radio,** *EURASIP Journal on Wireless Communications and Networking*, 2013, 2013:21.

[4] Jacques Palicot, Honggang Zhang, Christophe Moy. **On the Road Towards Green Radio,** *The Radio Science Bulletin*, 2013, pp.40-56

International Conferences (27)

2017

[1] Mouna Ben Mabrouk, Marwa Chafii, Yves Louët, Faouzi Bader, **Low-PAPR Conditions for 5G-candidate waveforms**, 32nd General Assembly and Scientific Symposium of the international Union of Radio Science (URSI GASS), 2017.

[2] Mouna Ben Mabrouk, Marwa Chafii, Yves Louët, Faouzi Bader. **A Precoding-based PAPR Reduction Technique for UF-OFDM and Filtered-OFDM Modulations in 5G Systems,** *European Wireless 2017*, May 2017, Dresden, Germany

[3] Ali Cheaito, Mohamed Saad Farah, Matthieu Crussière, Jean-François Hélard and Yves Louët, **Spectral Analysis of Predistorted Non-Linear Amplified Multicarrier Signals,** *IEEE Wireless Communications and Networking Conference (WCNC 2017),* San Francisco, CA, USA.

[4] N. Modi, P. Mary, C. Moy, S. Darak, **« Proof-of-Concept: Spectrum and Energy Efficient Multi-User CR Network via Vacancy and Quality based Channel Selection »**, *32nd General Assembly and Scientific Symposium of the international Union of Radio Science (URSI GASS),* Montreal, Canada

[5] MOLINA Laudin, BLANC Alberto, MONTAVONT Nicolas, SIMIĆ Ljiljana, **Identifying Channel Saturation in Wi-Fi Networks via Passive Monitoring of IEEE 802.11 Beacon Jitter**. MobiWac 2017 : 15th ACM International Symposium on Mobility Management and Wireless Access, ACM, 21-25 november 2017, Miami Beach, United States, 2017, pp. 63-70, ISBN 978-1-4503-5163-8

2016

[1] Navikkumar Modi, Philippe Mary, Christophe Moy, **A New Evaluation Criteria for Learning Capability in OSA Context,** *11th EAI International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM)* : 2016

[2] Sumit J. Darak, Navikkumar Modi, A. Nafkha, Christophe Moy, **Spectrum Utilization and Reconfiguration Cost Comparison of Various Decision Making Policies for Opportunistic Spectrum Access Using Real Radio Signals** *11th EAI International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM)* : 2016

[3] Marwa Chafii, Yahya J. Harbi, Alister G. Burr, **Wavelet-OFDM vs. OFDM: Performance Comparison,** *23rd International Conference on Telecommunications ICT*, Thessaloniki, Greece, 2016

[4] Marwa Chafii, M. Lamarana Diallo, Jacques Palicot, Faouzi Bader, Rémi Gribonval, **Adaptive Tone Reservation for better BER Performance in a Frequency Selective Fading Channel,** *IEEE 83rd Vehicular Technology Conference*: VTC2016-Spring, Nanjing, China, 2016.

[5] Ali Cheaito, Matthieu Crussière, Jean-François Hélard, Yves Louët, **Energy-Efficiency Optimization of the High Power Amplifier for Multicarrier Systems: Analytical EVM Derivation,** *IEEE Conference on Computer Communications Workshops* (INFOCOM WKSHPS 2016), San Francisco, CA, 2016 **(Best Paper Award)**

[6] A. Cheaito, Y. Louët, M. Crussière and J. F. Hélard, **Optimal operating point of the power amplifier with respect to the EVM for TV broadcasting applications**, *In proc. of the 2016 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, Nara, Japan, 2016.

[7] A. Mahbubul-Alam, P. Mary, J.-Y. Baudais, X. Lagrange, **Energy Efficiency-Area Spectral Efficiency Tradeoff in PPP Network with SLNR Precoder**, *In proc. of the 17th IEEE international workshop on Signal Processing Advances in Wireless Communications, SPAWC 2016,* Edinburgh, Scotland.

[8] Shehadeh, D. and Kerdoncuff, T. and Blanc, A. and Montavont, N., **How to wake up an access point?** WD 2016 : IFIP Wireless Days : 2016

[9] M. Chafii, J. Palicot, R. Gribonval, and A. Burr. **Power Spectral Density Limitations of the Wavelet-OFDM System**, *24th European Signal Processing Conference (EUSIPCO)*, Aug 2016, Budapest, Hungary.

[10] M.L. Diallo, M. Chafii, J. Palicot, F. Bader, **Modified Tone Reservation for PAPR Reduction in OFDM Systems,** *24th European Signal Processing Conference (EUSIPCO)*, Aug 2016, Budapest, Hungary.

2015

[1] Laura Melian-Gutiérrez, Navikkumar Modi, Christophe Moy, I. Perez-Alvarez, F. Bader, S. Zazo, **Upper Confidence Bound learning approach for real HF measurements,** *IEEE International Conference on Communication Workshops* (ICCW), 2015, London UK.

[2] Thomas Oberlin, Christian Barillot, Rémi Gribonval, Pierre Maurel, S**ymmetrical EEG-FMRI Imaging by Sparse Regularization,** *EUSIPCO – 23rd European Signal Processing Conference*, Nice, France, 2015

[3] Al Haj Hassan, H. and Gamboa, S. and Nuaymi, L. and Montavont, N. and Pelov, A., **The Smart Grid and Future Mobile Networks: Integrating Renewable Energy Sources and Delay Tolerant Users,** *IEEE 82nd Vehicular Technology Conference* VTC 2015-Fall, Boston, MA, USA 2015

[4] Shehadeh, D. and Montavont, N. and Blanc, A. and Kerdoncuff, T., **Minimal Access Point Set in Urban Area Wifi Networks,** *13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks*, *WiOpt 2015*, Mumbaï, India, 2015

[5] Gamboa, S. and Pelov, A. and Montavont, N.: **Changing paradigms for green cellular networks: The case of delay-tolerant users,** 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks, *WiOpt 2015*, Mumbaï, India, 2015

[6] Ali Cheaito, Jean-François Hélard, Matthieu Crussière, Yves Louët, **Impact of Clipping on EVM of the Predistorted Non-Linear Amplified Multicarrier Signals,** *IEEE Twelfth International Symposium on Wireless Communication Systems (ISWCS'15)*, Brussels, Belgium, 2015

[7] Ali Cheaito, Matthieu Crussière, Yves Louët, Jean-François Hélard, **EVM Derivation for Multicarrier Signals: Joint Impact of Non-Linear Amplification and predistortion,** *IEEE Vehicular Technology Conference (VTC Spring)*, Glasgow UK, 2015

[8] Ahmad Mahbubul Alam, Philippe Mary, Jean-Yves Baudais, Xavier Lagrange, **Energy Efficiency-Spectral Efficiency Tradeoff in Interference-Limited Wireless Networks with Shadowing,** *IEEE 82nd Vehicular Technology Conference: VTC2015-Fall*, Boston, MA, USA, 2015

[9] Navikkumar Modi, Philippe Mary, Christophe Moy, **QoS driven Channel Selection Algorithm for Opportunistic Spectrum Access, I**EEE Globecom Wokshops, San Diego, CA, USA 2015

2014

[1] Marwa Chafii, Jacques Palicot, Rémi Gribonval, **Closed-form Approximations of the PAPR Distribution for Multi-Carrier Modulation Systems,** *EUSIPCO 2014 - European Signal Processing Conference,* Lisbon Portugal 2014

[2] Marwa Chafii, Jacques Palicot, Rémi Gribonval, **A PAPR upper bound of generalized waveforms for multi-carrier modulation systems,** *6th International Symposium on Communications, Control, and Signal Processing - ISCCSP 2014*, Athens, Greece 2014

[3] Diallo M. L., Palicot J.: **Adaptive clipping for a deterministic PAPR,** *Third International Conference on Telecommunications and Remote Sensing - ICTRS,* Luxembourg, 2014.

International Workshop (1)

Navikkumar Modi, Christophe Moy, Philippe Mary, **Experimental Performance Comparison and Analysis for Various MAB Problems under Cognitive Radio Framework,** *Wireless Innovation Forum European Conference, WinnComm Europe'14*, Roma, Italy, 4-6 November 2014 (presentation only).

National Conferences (9)

2017

[1] Ahmad Mahbubul Alam, Philippe Mary, Jean Yves Baudais, Xavier Lagrange, **Compromis efficacités énergétique et spectrale du précodeur SLNR dans un réseau cellulaire aléatoire**, *XXVIème colloque GRETSI, GRETSI'17*, Juan Les Pins, 2017.

[2] N. Modi, P. Mary, C. Moy, **Apprentissage machine pour l'optimisation énergétique des réseaux cellulaires hétérogènes sans-fil : une approche bandit à bras multiples**, *XXVIème colloque GRETSI, GRETSI'17*, Juan Les Pins, 2017.

[3] A. Cheaito, J.F. Hélard, Y. Louët, M. Crussière, **Expression analytique du spectre pour les signaux multiporteuses : impact conjoint des non linéarités de l'amplificateur de puissance et de la fonction de prédistorsion,** *XXVIème colloque GRETSI, GRETSI'17*, Juan Les Pins, 2017.

2016

[1] N. Modi, C. Moy, P. Mary, **Machine Learning for Opportunistic Spectrum Access with Energy Consumption Constraint**, *URSI France, Energy and Radio Science* CentraleSupélec, Rennes, 2016

[2] Marwa Chafii, Jacques Palicot, Rémi Gribonval, **La modulation en ondelettes: une modulation alternative à faible consommation d'énergie** *URSI France, Energy and Radio Science* CentraleSupélec, Rennes, 2016 **Best Paper Award.**

[3] Nicolas Montavont, Dareen Shehadeh, Jacques Palicot, Xavier Lagrange, Alberto Blanc, Rémi Gribonval, Philippe Mary, Jean-Yves Baudais, Jean-François Hélard, Matthieu Crussière, Yves Louet, Christophe Moy, **Toward Energy Proportional Networks,** *URSI France, Energy and Radio Science* CentraleSupélec, Rennes, 2016

2015

[1] Marwa Chafii, Jacques Palicot, Rémi Gribonval: **L'optimalité de l'OFDM en termes de performance en PAPR,** *XXVème colloque GRETSI, GRETSI'15*, Lyon 2015.

[2] Navikkumar Modi, Philippe Mary, Christophe Moy, **Apprentissage machine orienté QoS pour l'accès opportuniste au spectre,** *XXVème colloque GRETSI, GRETSI'15*, Lyon 2015.

[3] Ali Cheaito, Matthieu Crussière, Yves Louët, Jean-François Hélard: **Expression analytique de l'EVM pour les signaux multiporteuses : impact conjoint des non linéarités de l'amplificateur de puissance et de la fonction de prédistorsion,** *XXVème colloque GRETSI, GRETSI'15*, Lyon 2015.