Radio link characterization of the CorteXlab testbed with a large number of software defined radio nodes

Achille Mouaffo, Leonardo Cardoso, Hervé Boeglen, Guillaume Villemaud, Rodolphe Vauzelle

To cite this version:

Achille Mouaffo, Leonardo Cardoso, Hervé Boeglen, Guillaume Villemaud, Rodolphe Vauzelle. Radio link characterization of the CorteXlab testbed with a large number of software defined radio nodes. Antennas and Propagation (EuCAP), 2015 9th European Conference on , Apr 2015, Lisbon, Portugal. hal-01245107

HAL Id: hal-01245107

https://hal.inria.fr/hal-01245107

Submitted on 16 Dec 2015

Radio link characterization of the CorteXlab testbed with a large number of software defined radio nodes

Achille MOUAFFO[1,2], Leonardo CARDOSO[2], Hervé BOEGLEN[1], Guillaume VILLEMAUD[2], Rodolphe VAUZELLE[1]
[1] Laboratory XLIM-SIC, UMR CNRS 6172, University of Poitiers, SP2MI-Téléport 2-Boulevard Marie et Pierre Curie-BP 30179, 86962 Futuroscope Chasseneuil Cedex, France
[2] Université de Lyon, INRIA, INSA-Lyon, CITI-INRIA, F-69621, Villeurbanne, France

***Abstract*—This paper presents the first implementation on software defined radio nodes in the large scale testbed called CorteXlab of a radio link estimation technique based on OFDM transmissions. The purpose of this large scale testbed is to offer to the whole scientific community an open tool to test new techniques for multi-user, cooperative and cognitive radio networks in a controlled environment. As the experimentation room was defined in order to offer reproducible measurements, it is important to be able to characterize each radio link between all transceivers. Therefore, we present here the development of a channel sounder directly implemented on the software radio nodes.**

***Index Terms*—propagation, measurement, software defined radio.**

I. INTRODUCTION

In the future internet of things, wireless technologies will represent a large part of the market in weak competition with power line or infrared communications. Up to now, standards have been developed with a bottom-up approach and the radio spectrum sharing policies are mostly static. Since billions of objects are expected to use wireless links, the present way the wireless medium is shared has to be revisited. For such, radio systems, algorithms and protocols have to be deeply transformed.

The most promising approach stems from the cognitive radio paradigm, which relies on three complementary mandatory properties: all radio systems real-time reconfigurability, wireless environment awareness behavior, and self-organization capability. The first item is referred to as software defined radio (SDR), the second as cognitive radio (CR) and the third as self-optimization networks (SON).

In this paper, we will present the CorteXlab testbed [1], a large scale testbed open to the scientific community to test, evaluate and optimize current or future wireless systems, particularly focusing on multi-user, cooperative and cognitive networks. We will first present the globality of this testbed, then detail the problem and implementation of a channel sounder on this kind of SDR nodes, and finally present some preliminary results and draw some conclusions.

II. PRESENTATION OF THE CORTEXLAB TESTBED

A. Motivation for this large scale testbed

A valuable platform able to test realistic future scenarios, should offer the possibility to evaluate simultaneously these three items to support the actual theoretical developments from an experimental point of view. Unfortunately, a platform that contemplates all of these topics at the same time does not currently exist. CorteXlab aims to fill in this gap. The CorteXlab testbed will be hosted at INSA-Lyon in France, benefiting from the Senslab (now FIT/IoT-lab) experience and from the 5 years experience on developing a MIMO (Multiple Input Multiple Output) high data rate reconfigurable platform. CorteXlab will use the network architecture developed in IoT-lab and will integrate SDR nodes to offer a remotely accessible development platform for distributed Cognitive Radio (CR). Reconfigurability, compatibility, coexistence and even cooperation between SDR nodes will be evaluable. A large set of heterogeneous SDR nodes (MIMO nodes, SISO nodes and Wireless Sensor Network (WSN) nodes) will permit a full experimental evaluation.

CorteXlab will allow remote users to test their own algorithms on the existing nodes, but the architecture will be also opened to industry third party to deploy their own front-end (RF or UWB) or baseband systems to test and validate their developments. A clear expected result is offering a remote access to all equipments in a comprehensive way, such that many scenarios can be evaluated by remote users. A second target is to create a “network of SDR” development community including people from digital communications, networking and embedded systems, to provide a complete set of functionalities and also enroll interesting industrial partners to include in the platform new SDR or front end components.

B. Numbers and facts

To address all of these issues we introduce CorteXlab [1], a testbed composed of 82 heterogeneous and high performance radio nodes deployed in an electromagnetically isolated room, for cutting edge radio experimentation. With CorteXlab, our main objective is to provide a unified and comprehensive access to a large set of heterogeneous nodes in a reproducible environment, in the aim to foster experimental development of future radio techniques. CorteXlab offers 22 USRPs 2932 from National Instrument, 18 PicoSDRs from Nutaq and 42 IoT-Lab wireless sensor nodes from Hikob. It makes available the full potential of SDR, through the widely accepted GNU Radio toolkit as well as high performance real-time field programmable gate array (FPGA) development. The SDR hardware available in CorteXlab ranges from simplistic wireless sensor network (WSN) nodes to full blown 4x4 MIMO SDR nodes with agile radio capabilities. Through a carefully designed backbone network, those radio nodes are capable of cooperating to emulate complex radio technologies such as network multiple input – multiple output (MIMO) [2], interference alignment (IA) [3] and physical layer based relay networks.

CorteXlab is developed, along with 8 other testbeds, under the framework of a nationwide French program Future Internet of Things (FIT) [4]. FIT aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of users.

The inaugural meeting of this CorteXlab testbed will be held the 28th of October 2014, and then CorteXlab will be officially open to the community for experimentations.

Fig. 1. Pictures of the CorteXlab testbed, part of the FIT equipment of excellence

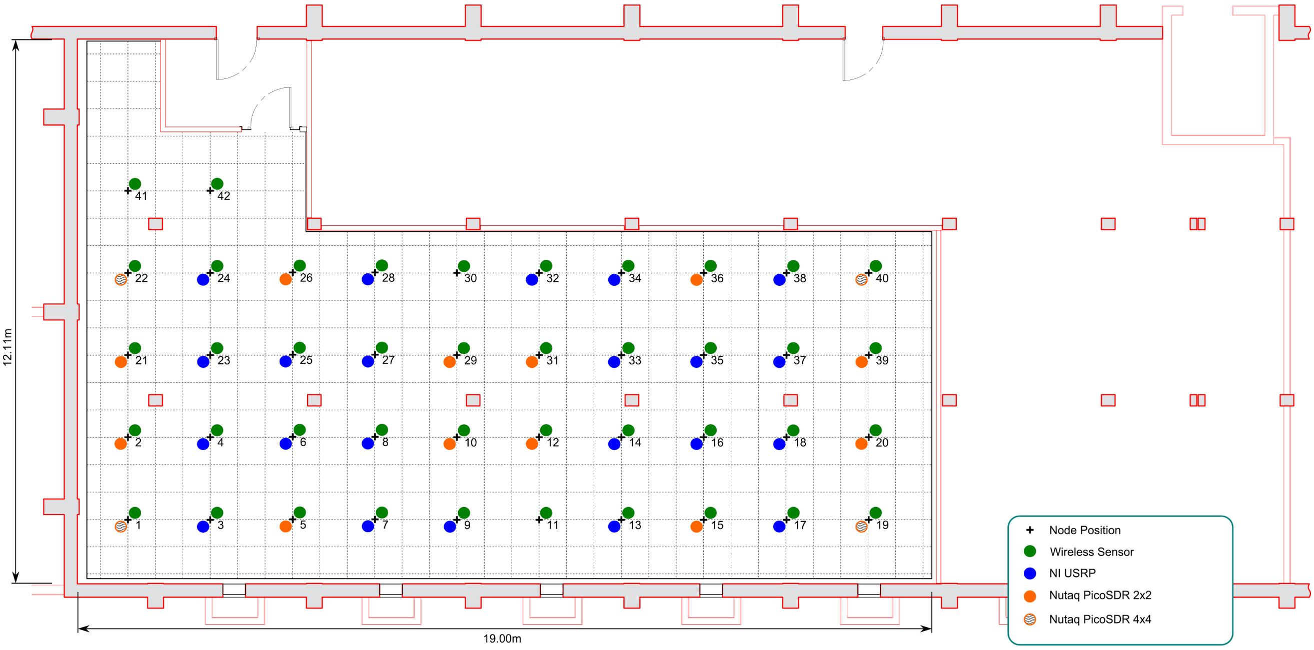

Fig. 2. Positions of the wireless transceivers in the CorteXlab testbed: in green WSN, in blue USRP, in orange PicoSDR 2x2, in grey PicoSDR 4x4

III. CHANNEL CHARACTERIZATION BASED ON USRP

In order to characterize all possible radio links between the different wireless nodes in this testbed, we have developed a channel sounding technique directly based on the USRP nodes. This sounder is obviously limited in quality by the intrinsic radio characteristics of these USRP, but this will enable an easy-to-use and easy-to-deploy solution for all future users in order to have an evaluation of the channel linking each pairs of transceivers. This channel sounder has been adapted from a previous work presented in [5] and redesign for this special purpose.

A. *Experimentation room*

CorteXlab counts with a completely shielded room to ensure EM isolation with the outside world. This allows the use of any (restricted or open) frequency between 300 MHz and 5 GHz, which might appeal to researchers looking to test specific frequency or standard related techniques. It also improves reproducibility since all sources of interference and channel impairments are confined to the interior of the room. To avoid excessive reflections, EM wave absorbing foams cover all walls and roof, leaving room from some reflections to occur. A glimpse of the experimentation room can be seen in Figure 1.

A measurement campaign has shown an attenuation of more than 80 dB is ensured in the band [800MHz-5GHz], with at least 60 dB throughout the whole target band. We are well aware that by shielding the room, a risk is taken on producing an unrealistic propagation environment. To properly assess the radio environment with the EM shielding, two approaches are currently under study. In the first approach, an extensive ray-tracing simulation campaign could provide an initial understanding of the expected kind of propagation environment, and then allow (if needed) the subsequent placement of absorbers or reflection surfaces to improve the radio characteristics of the room. The second approach, subject of the presented study, consists on running a campaign of channel measurements to properly assess the effectiveness of the changes made in the first step, as well as to provide real channel measurements to our future users. Finally, cameras will also be installed in the room to diminish human intervention to a minimum.

B. *USRP software defined radio nodes*

Represented by the National Instruments USRP 2932, the general-purpose SDR nodes will use (but are not limited to) the GNU Radio toolkit for rapid prototyping of transmission techniques mostly reliant on the general purpose processor (GPP) of the host PC. The USRP 2932 [6] is a high end radio platform, counting with a 400 MHz – 4.4 GHz RF board, data rates of up to 40 MHz (with reduced dynamic range, nominal band of 20 MHz), a precise OCXO clock source and a 1 gigabit ethernet (GigE) connection to the host PC. The host PC is based on a Linux environment and will allow users to test not only PHY layer techniques, but also MAC, NET, TRA and APP, by deploying custom kernel modules that can coexist with the stock implementations easily.

Both the use of Linux and GNU Radio will facilitate the development and test at the user's own computer before bringing the experiment over to CorteXlab. Furthermore, the GNU Radio and Linux communities have progressed a lot in the last decade, offering good and free support to users as well as a multitude of open and accessible examples, which can be downloaded off the internet and used without additional charges.

C. *Channel sounder*

The GNU radio API is based on two languages. Python is in charge of setting up the signal processing flow graph forming the transceiver chain and for the synchronization between blocks. The signal processing blocks which require a high processing power are written in C++. The relation between Python and C++ is made by SWIG [7].

There already exist a lot of applications running on USRPs in several domains ranging from ZigBee to GSM. There is also an 802.11p transmitter application designed by Fuxjäger et al. [8]. We have used this implementation as a starting point for our design. The IEEE 802.11p physical layer has similar specifications as IEEE 802.11a with some changes. In IEEE 802.11p, a 10MHz frequency bandwidth is used, instead of 20MHz bandwidth in IEEE 802.11a, thus all parameters in the time domain for IEEE 802.11p are doubled compared with IEEE 802.11a. Intrinsically, 802.11p uses OFDM.

When implementing an 802.11p transceiver, the best method we found was to use Annex G of the standard [9]. It is a complete example of a packet encoding which gives the results of the encoding at the end of each block ending up with the baseband IQ vectors. We did the same for the corresponding blocks of the decoder. At this point, we had everything needed to simulate an 802.11p transmission [5]. In order to perform a real transmission, Automatic Gain Control (AGC) and synchronization at the receiver is needed.

But for a channel sounding application, we only need to capture the signal after it has passed through a 10MHz bandpass filter and the AGC. The synchronization and the decoding of the packets can therefore be performed off line using Matlab.

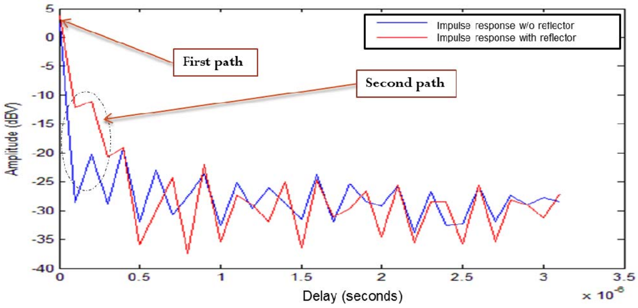

Fig. 3. Impulse responses of a transmission between two USRPs in the CorteXlab testbed, with only one direct path (blue) or with two paths (red) using a reflector

Of course, one important limitation of using USRPs for this channel sounding is that the resolution is relative to the 10 MHz of bandwidth used. As a matter of example of this limitation, we can show in Fig. 3 that we can only resolve two paths if we plot the impulse response of the system in the largest dimensions of the room. This test was performed using a directive antenna at the emitter, creating a direct path to the receiver and one bouncing path on a reflector. Then we can achieve to separate these two paths only if we use all the length of the room.

D. Some first results

In order to promote the automated control of all nodes during an experiment, an experimentation control plane was created, called Minus. It allows for the scheduling, deployment, start, finish and results collection of user experiments.

Each experiment is organized as a Minus task, and contains:

- Scenario description: a textual file with the list of nodes, their roles and their parameters;
- Scenario roles: the actual firmware, GNU Radio Python scripts, pre-compiled libraries, pre-compiled C code and FPGA bitstreams that define the node behavior during the experiment;
- Role parameters: the configuration values that refine the behavior of each role.

Therefore, the GNU radio code developed to realize the channel sounding was used as a source for Minus in order to attribute roles of one emitter and 21 receivers in each experimentation. Up to now, a first run of experimentations was performed, with 6 nodes as emitters, so 126 links in total. After analysis, we could already say that, on those 126, 110 could be considered as mainly LOS, only 10 have a strong NLOS behavior and finally 6 are too weak to allow demodulation of the signal.

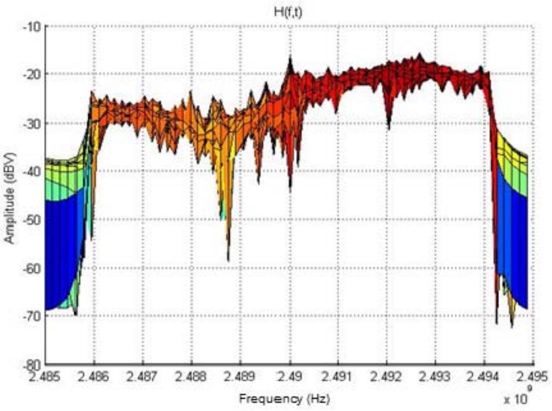

Fig. 4. Radio link evaluation in frequency domain between nodes 37 and 18

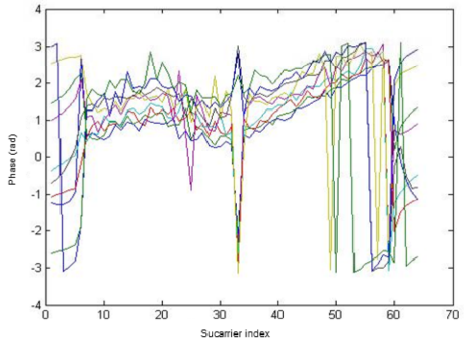

Fig. 5. Phase distribution on each subcarrier for the link between nodes 37 and 18

Another interesting and simple result is the ability with this scheme to evaluate the attenuation of the signal on each link, resulting in a global value of the mean pathloss. Moreover, if we want to characterize the effect of shadowing and fading for each link, this could be more difficult with the limitation of this platform, but not necessarily meaningful for network-level users. The mean power received on each subcarrier could be sufficient information (as shown in Fig. 4) as the controlled environment is static.

But in order to give an evaluation of the diversity order offered depending on the chosen link, an interesting analysis could be based on the phase of each subcarrier. Fig. 5 shows a typical example of a NLOS scenario where the phase distribution is non-linear, resulting in higher diversity.

CONCLUSION

This paper has presented the development of a channel sounder in order to characterized all radio links in the new CorteXlab testbed. Some first results are exposed, now an extensive campaign has to be launched to fully characterized all possible links, and potentially to increase the number of metrics that are transmitted to the users.

REFERENCES

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

[2] S. Venkatesan, A. Lozano, and R. Valenzuela, “Network mimo: Overcoming intercell interference in indoor wireless systems,” in Signals, Systems and Computers, 2007. ACSSC 2007. Conference Record of the Forty-First Asilomar Conference on. IEEE, 2007, pp. 83–87.

[3] V. R. Cadambe and S. A. Jafar, “Interference alignment and the degrees of freedom for the k user interference channel,” arXiv preprint arXiv:0707.0323, 2007.

[4] http://fit-equipex.fr.

[5] H. Boeglen, B. Hilt, R.Vauzelle, “A poor man’s VANET channel sounder”, IEEE ISIVC 2012, Valenciennes, France, July 4-6, 2012.

[6] http://www.ni.com/usrp/

[7] http://www.swig.org/

[8] P. Fuxjäger, A. Costantini, D. Valerio, P. Castiglione, G. Zacheo, T. Zemen, F. Ricciato, “IEEE 802.11p Transmission Using GNURadio”, 6th Karlsruhe Workshop on Software Radios, March 2010.

[9] 802.11-2007 - IEEE Standard for Information technology -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Laye (PHY) Specification.