CorteXlab: An open FPGA-based Facility for Testing SDR & Cognitive Radio Networks in a Reproducible Environment

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***Abstract*—While many theoretical and simulation works have already highlighted the potential gain of cognitive radio, several technical issues still have to be evaluated and overcome from an experimental viewpoint. Our team is currently developing a new experimental facility remotely accessible and dedicated to this problem. *CorteXlab* is developed in the framework of a nationwide French program Future Internet of Things which proposes a federated and competitive infrastructure. The *CorteXlab* facility offers a $167m^2$ EM shielded room and integrates a set of 22 USRP from National Instrument, 16 *picoSDR* nodes from *Nutaq* and 42 IoT-Lab wireless sensor nodes from Hikob. *CorteXlab* is built on the network architecture developed for the SensLAB testbed and exploits the free and open-source toolkit GNU-radio. All nodes are remotely accessible through a software interface called Minus. The demo presented at Infocom describes the facility and shows the process a user should follow to deploy his own experiment. Two typical scenarios involving several nodes are built and deployed live. The first scenario is based on IEEE 802.15.4 communication between two *picoSDR* nodes. The second scenario is dealing with an avoiding-interference use case where the previous two *picoSDR*s are communicating while a cognitive MIMO-OFDM transceiver running on one *picoSDR* must avoid interference with them.**

I. State of the Art

Cognitive radio (CR) is a paradigm that refers to dynamic radio resource sharing among heterogeneous wireless systems. CR is clearly expected to play a fundamental role in a near future, allowing coexistence of multiple radios in a unique frequency band. CR could permit a very high spectral efficiency and reuse but relies on a perfect usage of software radio technologies.

Large-scale cognitive radio testbeds are required to develop and evaluate the performance of upcoming PHY/MAC layers and future cognitive radio algorithms. Unfortunately, testing new algorithms on real testbeds is complex and time-consuming. While many groups deployed their own facilities, comparing algorithms and techniques in different setups while ensuring reproducible experiments appeared not yet accessible.

Whereas numerous testbeds are available in the field of wireless communications (sensor or 802.11-oriented), only a few large-scale testbeds have been developed having full SDR and cognitive radio capabilities. Apart from on-going projects such as CREW [1] or TRIAL [2] and some small testbeds involving less than 10 nodes, we found only two testbed developed respectively at Rutgers University, ORBIT [3] and at Virginia Tech., CORNET, where USRP2 have been dispatched in the ceilings. On both cases, the registered users can remotely program and run experiments on the USRP2.

Both facilities are already offering a remote access with strong cognitive radio capabilities. However, we note that both facilities have their nodes deployed in a conventional environment, which means that the system may suffer from external interference while itself may produce interference on any extern operational system. In both cases, the cognitive radio nodes are based on the USRP technology which present some limitations in terms of bandwidth and real-time capabilities.

II. CorteXlab facility

CorteXlab [4], as part of the Future Internet of Things [5] french funding, is a new testbed made of about 38 software defined radio (SDR) nodes together with 42 wireless sensor nodes. The main objective is to enable users to run real-time communications with custom APP (application such as traffic generation), MAC (medium access control) and PHY layers implementing state-of-the-art (WiFi, Zigbee, LTE, LTE-A.) and upcoming (5G) standard and the programmability of the platform is a key factor of success.

Our testbed is complementary to those of CORNET and ORBIT through the shielded room that targets reproducibility and control over the radio propagation and through the heterogeneity of the nodes. The room is indeed completely faradized on the 6 faces and EM wave absorbing foams cover all walls and roof. Measurements showed that an attenuation of more than $80dB$ is ensured in the band $[500MHz-5GHz]$. Following the conclusions of the previous section, we chose to mix two types of nodes in the testbed: general-purpose CPU nodes and FPGA-based SDR nodes. The former (typically USRP) are able to run GNU radio, an open source environment, for rapid prototyping at slow data rates, while the later should be able to run advanced MIMO PHY layers. The difference between both nodes relies on the size of the FPGA and the functions of the PHY layer that are assigned to it.

The deployment of a scenario follows the following workflow: the remote user connects to the virtual machine "Airlock" which is the only machine an end user can reach through SSH. From Airlock, the user has access to his home directory and uses the tools provided by *CorteXlab* to compile his code and generate the scenario description file. When ready, the user sends a task request to Minus which schedules and installs the code on the nodes.

III. Scenario

In this contribution we demonstrate the remote accessibility to *CorteXlab*. A typical scenario involving several *Nutaq picoSDR* nodes is built and deployed live, highlighting the steps a user should follow to deploy his own experiment. *picoSDR* platform allows using three design flows: BSDK (Board Support Design Kit), MBDK (Model Based Design Kit) and GNU Radio design flow. BSDK is the design flow adopted in the context of *CorteXlab* testbed to enable HDL design and implementation of open source IPs for SDR systems. However, users who already have available *Nutaq picoSDR*s can develop their own FPGA-based baseband design according to one of those design flows. A *picoSDR* job developed according to BSDK or MBDK design flow must contain a bitstream targeting FPGA and an ANSI C program that should run on the computer. The latter uses the *Nutaq* EAPI, which is an open source library, distributed under GPL license. It allows developing software application, routing algorithms and MAC protocols. A GNU radio based design targeting *picoSDR* must contain the GNU Radio job that should run on the host machine. The matching bitstream is available on *CorteXlab* testbed and will be loaded on the FPGA by Minus. To configure and program a *picoSDR*, the node deployment tool has a standalone *Xilinx* and *Digilent* software tools to allow programming *picoSDR* remotely.

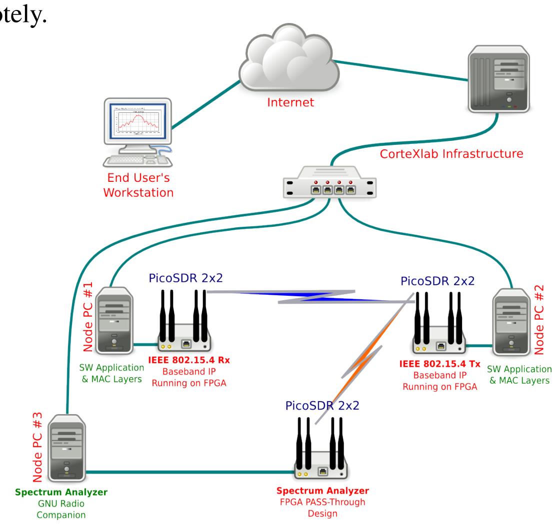

Fig. 1. An IEEE 802.15.4 communication scenario.

Two typical scenarios involving several nodes are built and deployed live. The first scenario is based on IEEE 802.15.4 communication between two *picoSDR* nodes as illustrated in Fig. 1. The second scenario deals with an avoiding-interference use case where the previous two *picoSDR*s are communicating while a cognitive MIMO-OFDM transceiver running on one *picoSDR* must avoid interference with them as depicted in Fig 2. Moreover, in both cases, a *picoSDR* is used as a GNU Radio based remote spectrum analyzer to forward the spectrum state to the end user.

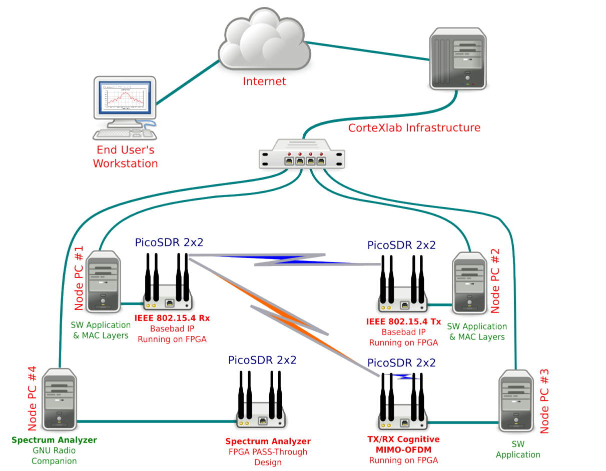

Fig. 2. An Interference Avoidance scenario based on IEEE 802.15.4 and cognitive MIMO-OFDM transceivers.

IV. Conclusion

To the best of our knowledge, *CorteXlab* is the first facility offered to the research community allowing to remotely experiment cognitive radio scenarios in a completely reproducible environment. Compared to existing facilities, *CorteXlab* provides two important new features: the first is the coexistence of heterogeneous technologies and the second is the shielded room. Last but not least, the co-existence of simple low power wireless sensor networks (IoTlab WSNs) together with complex software radio nodes open the door for new original and complex scenarios. For instance, when the software radio nodes are programmed to evaluate different resource sharing algorithms, interference and thus reproducibility is ensured. But the software radio nodes can also be used to generate a specific interference environment in which the robustness of routing protocols in IoTlab WSNs could be evaluated. Furthermore, mobile robots will be also added in the room vehiculing radio nodes and allowing to simulate mobility scenarios. The remote access and the procedure to deploy a *picoSDR*-based scenario are illustrated. The proposed scenario uses a *CorteXlab* IEEE 802.15.4 design and *Nutaq* cognitive MIMO-OFDM design to illustrate an interference avoidance use case. However, this will not prevent the use of a user-made bitstream as long as it is compatible with *picoSDR* platform.

References

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