

# Demo: Online Evaluation of Sensing Characteristics for Radio Platforms in the CREW Federated Testbed

Virgilios Passas<sup>⊕</sup>, Kostas Chounos<sup>⊕</sup>, Stratos Keranidis<sup>⊕</sup>, Wei Liu<sup>\*</sup>, Lieven Hollevoet<sup>†</sup>, Thanasis Korakis<sup>⊕</sup>, Iordanis Koutsopoulos<sup>⊕</sup>, Ingrid Moerman<sup>\*</sup> and Leandros Tassiulas<sup>⊕</sup>

<sup>⊕</sup>Department of Computer and Communication Engineering, University of Thessaly, Greece

<sup>○</sup>Centre for Research and Technology Hellas, CERTH, Greece

<sup>\*</sup>Ghent University - iMinds, Gent, Belgium

<sup>†</sup>IMEC Wireless Research, Leuven, Belgium

{vipassas, hounos, ekerani, korakis, jordan, leandros}@uth.gr  
{wei.liu, ingrid.moerman}@intec.ugent.be  
{lieven.hollevoet}@imec.be

## ABSTRACT

Cognitive radio systems have gathered a lot of research interest during the last decade. Accuracy of spectrum sensing and efficiency of free spectrum utilization are considered as the primary objectives in this emerging technology, which promises a boost in wireless network performance, through exploitation of underutilized licensed frequency bands. As the focus of researchers is usually on these two major challenges, other aspects have been in part underestimated. In this work, we consider two factors that are rather important for evaluation of cognitive platforms, namely sensing delay and energy efficiency. The first is related to the latency induced by the spectrum sensing process and its impact on sensing efficiency, which is tightly connected to both the QoS performance of secondary users and the protection of primary users. On the other hand, energy consumption is considered as a crucial issue in all types of wireless communications, due to restricted battery autonomy of mobile devices, as well as for moving towards “greener” solutions in telecommunications. Therefore, it is important to extend existing testbed experimentation tools and develop new ones, in order to equip cognitive testbeds with such advanced monitoring capabilities. In this work, we present a monitoring procedure that has been directly integrated in the experimentation tools of the CREW testbed federation and demonstrate how it aids in the online evaluation of four different cognitive platforms in terms of the aforementioned metrics.

## Categories and Subject Descriptors

C.2.1 [Computer-Communication Networks]: Network Architecture and Design - Wireless Communications

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## Keywords

Spectrum Sensing, Energy Consumption, CREW project

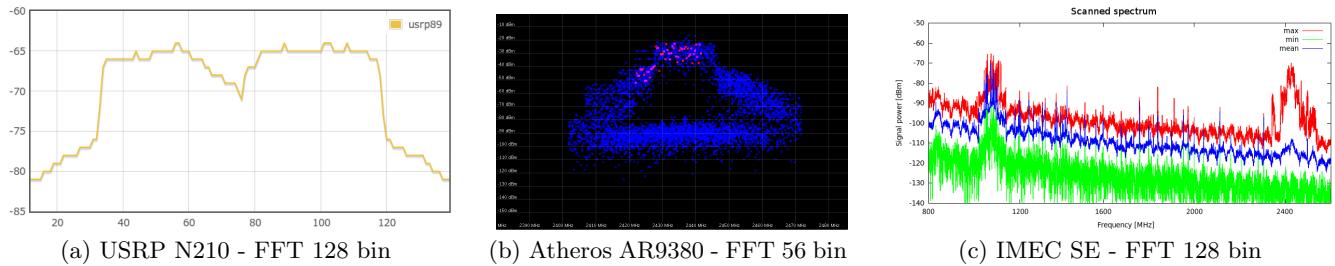
## 1. INTRODUCTION

Cognitive Radio Networking is a rapidly evolving research thrust in wireless communications nowadays, aspiring to create a major paradigm shift in the wireless landscape through Dynamic Spectrum Access and Management. In order to enable realistic cognitive radio experimentation, several devices that feature spectrum sensing capabilities have been developed. In this work, we will investigate the sensing characteristics of 4 different sensing devices under common spectrum sensing scenarios. The scenarios include spectrum sensing of a specific channel band through FFT processing of the captured data to characterise the Power Spectral Density (PSD) over the specified bandwidth. Under these reference scenarios, we will evaluate the 4 different devices in terms of the achieved sensing delay and resulting energy consumption.

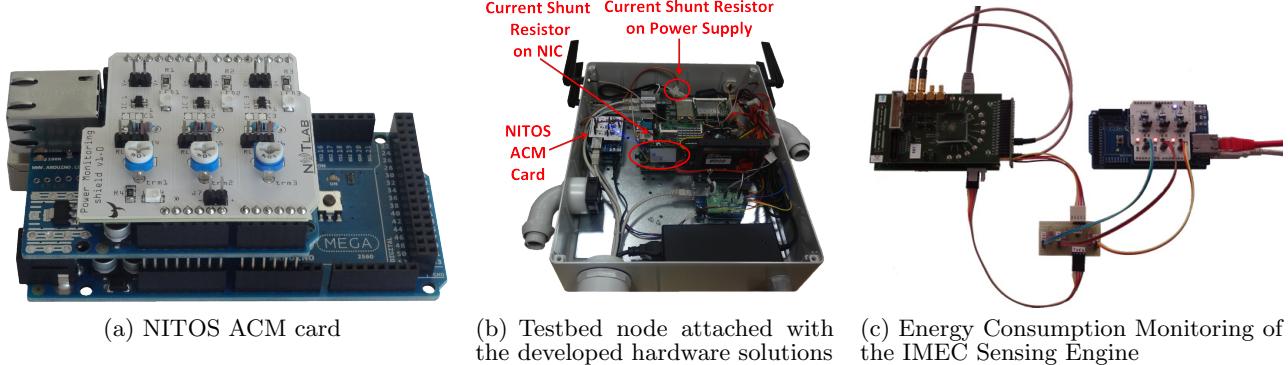
## 2. HARDWARE PLATFORMS

Devices under investigation are the well-established Universal Software Radio Peripheral (USRP) E110 Embedded Series [1], the USRP N210 Networked Series [2], the prototype IMEC Sensing Engine (SE) [3] and a commercial wireless network interface card (NIC) that features the Atheros AR9380 chipset [4]. The USRP devices are commercial SDR platforms, which mainly consist of two parts, a fixed mother board and a plug-in daughter board. The former contains ADC/DAC and an FPGA and the latter provides basic RF front-end functionality. We will equip both USRP devices with the XCSR2450 daughterboard, which operates in the 2.4 GHz and 5 GHz bands. The feature that differentiates the E110 from the N210 device is that it is equipped with an ARM Cortex-A8 cpu processor and thus does not require the use of a host pc for measurement processing. USRP N210 is capable of monitoring 25 MHz of bandwidth, limited by the maximum bandwidth of Gigabit Ethernet, while the USRP E110 device is limited to bandwidth sizes up to 8MHz, due to the reduced sampling rate and processing capabilities.

The IMEC SE consists of two core components: an analogue RF front-end SCALDIO (SCAlable raADIO) and a Digi-



**Figure 1: Screenshots of PSD estimations for different devices and configurations**



**Figure 2: Hardware components and modifications to sensing devices**

ital Front-end For Sensing (DIFFS). Both these ICs are low-power and flexible and targeted towards implementation of a cognitive radio as a mobile device. SCALDIO is a fully reconfigurable analog transceiver that features an FFT accelerator core, enabling the engine to perform spectral analysis with a default FFT size of 128 samples. The receiver RF operating frequency is programmable from 0.1 to 6 GHz and the channel bandwidth is programmable between 1 and 40 MHz.

The Atheros AR9380 chipset, which is also 3x3 MIMO compatible, is capable of performing spectrum sensing, by exploiting the open-source driver compat-wireless version 3.9 and above. AR9380 can generate  $4\mu\text{s}$  long spectral snapshots for any 20MHz wide channel among the 38 available ones in the 2.4 GHz and 5 GHz bands. The default driver implementation supports FFT calculations of 56-bin size, where each bin is used to characterise the PSD of each one of the OFDM subcarriers that are being used by IEEE802.11n standard. This NIC is enabled for spectrum sensing, so that interference of different wireless technologies (e.g. Zigbee) that operate on the same channel can also be detected.

### 3. METRICS AND EXPERIMENTATION

Considering the fact that the aforementioned sensing devices feature varying sensing capabilities, we will test them under two reference scenarios, to comparatively evaluate their performance in terms of sensing delay and energy efficiency. The first scenario includes the sensing of 8 MHz bandwidth of the 2.4 GHz band and the characterisation of the observed PSD. We decided to set the limited bandwidth of 8 MHz, so that all devices are able to gather measurements

without the need of switching their central frequency. Under this scenario, we will evaluate the sensing delay capabilities of the considered devices, which significantly varies due to the variance of both the measurement collection and measurement processing time across different platforms. Moreover, we will also consider a second scenario where the targeted band is 100 MHz wide, so that all devices will have to perform channel switching to provide for proper monitoring of the whole band. In this second scenario, we will also evaluate the sensing efficiency of all devices, which is related to the portion of time, during which spectrum is being continuously monitored. Indicative screenshots that correspond to PSD spectrum characterisation for different devices and FFT configurations are presented in Fig. 1. More specifically, Fig. 1(a) represents PSD estimation of the USRP N210 that monitors 25 MHz bandwidth of a single Wi-Fi channel with 128-bin FFT, while Fig. 1(b) represents data gathered through the Atheros AR9380 device and characterises the PSD of 11 consecutive Wi-Fi channels in the 2.4 GHz band. These results have been collected through 8 repetitive scans on the central frequency of each channel, where in each step 56-bin FFT calculations are performed. Finally, Fig. 1(c) illustrates the PSD estimation of the IMEC SE for the entire band between the 800 and 2600 MHz, as captured through 128-bin FFT calculations.

The considered devices include both embedded solutions (USRPE110 and IMEC SE) that do not require the use of a host machine for measurement processing and devices that are not capable of self-processing (USRP N210 and AR9380) and thus are attached to external PCs. As a result, the energy expenditure that each device results in significantly

varies. We will assess this interesting sensing performance - energy consumption tradeoff, by using the NITOS ACM card [5] that is able of gathering power measurements with increased sampling rate and accuracy. The NITOS ACM card is presented in Fig. 2(a), while Figures 2(b) and 2(c) show how we attach the card to a host PC, its NIC and the IMEC SE accordingly.

The two aforementioned experimental scenarios will be demonstrated live and the obtained results will be presented in parallel with the experiment execution.

## 4. DEMO REQUIREMENTS

For the purposes of this demonstration, we will bring:

- our projector and laptops
- the 4 Sensing devices available at the CREW Testbed and also 4 NITOS ACM cards,

while we will also require:

- a desk of 2 meters length to place the equipment,
- power supply plugs for all the devices.
- 20 minutes for setup and testing.

## 5. CONCLUSIONS

In this demo paper, we demonstrate a framework that enables evaluation of cognitive devices, in terms of sensing delay and resulting energy consumption. In particular, we present a monitoring procedure that has been directly integrated in the experimentation tools of the CREW facilities and demonstrate how it aids in the online evaluation of 4 different cognitive platforms in terms of the aforementioned metrics.

## 6. ACKNOWLEDGEMENTS

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## 7. REFERENCES

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