Bottom-up Broadband Pilots in Europe (C4EU 5.2.1: Report on Super WiFi Pilots - a)

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Abstract

Super WiFi provides different benefits to wireless deployments when compared with the IEEE 802.11b/a/g set of standards, like better wall penetration and longer ranges. The present technical report accounts for the implementation of a cognitive sensor built with an Universal Software Radio Peripheral (USRP) and the open Software Defined Radio (SDR) project GNURadio. This allows for the identification of TV White Spaces (TVWS) suitable for data transmissions.

Index Terms

Bottom-up-Broadband (BuB), super-wifi

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I. Introduction

Super WiFi is an emerging attempt to make use of the available spectrum in the UHF TV band (between 471.25 and 863.25 MHz) for wireless data transmissions. This spectrum availability is the result from the digital switchover of analog TV channels, allowing more TV data to be transmitted over the same 8 MHz-width UHF TV channel.

Some of the benefits of attempting transmission over these frequencies are longer ranges and better building penetration than in the unlicensed 2.4 and 5 GHz bands used by the IEEE 802.11 set of protocols. These benefits are followed by strict regulatory and technological challenges regarding the administration of TV White Spaces (TVWS) and cognitive capabilities for incumbent avoidance.

This report assesses some of Super WiFi's technical challenges, specially those related to incumbent detection and avoidance [1]. As a result, an energy detector on the UHF TV band is implemented using the Universal Software Radio Peripheral (USRP) Ettus USRP-E110 [2] as a radio front end for embedded applications (see Figure 1) and the open source Software Defined Radio (SDR) project GNURadio [3]. Furthermore, an instant image of the TV UHF band is derived from the detection (see Figure 3).

Section II overviews previous work in this area, followed by Section III which details the implementation of a spectrum sensor using the USRP-E110. Results are summarized in Section IV while conclusions and future directions are provided in Section V.

II. Related Work

In order to effectively transmit in the UHF TV band, it is mandatory to avoid interference with legacy users like wireless microphones, radio astronomy and existing TV channels. Wireless microphones are the ones that cause most of the problems when building a detector, mainly because of their narrow-band transmissions, low transmit power and (usually) unknown location.

There are several techniques for determining the presence of signal in the UHF TV band, namely energy detection [4], cyclostationary detection [5] and feature detection [6]. In this work, an energy detection approach is implemented due to its low complexity.

The proposed approach gathers the Power Spectral Density (PSD) of a set of samples taken every *SampleSteps* (SS) Hertz in a determined frequency band. After the gathering, post-processing carries the task of identifying which power levels could be considered as noise based on the statistics of the sampled spectrum.

The identification of White Spaces is performed in a standalone USRP-E110 (see Figure 1) using the WBX RX/TX Daughterboard [7], GNURadio [3] and a modified example code for spectrum sensing [8] to account for different RF daughterboards and antennas. Figure 2 presents the connection layout between the USRP-E110 and a PC. This connection was used to transmit the executable code to the USRP and then to retrieve the White Spaces estimation file.

Both the PC and USRP-E110 belong to the same subnet and the communication was established inside a standard SSH tunnel.

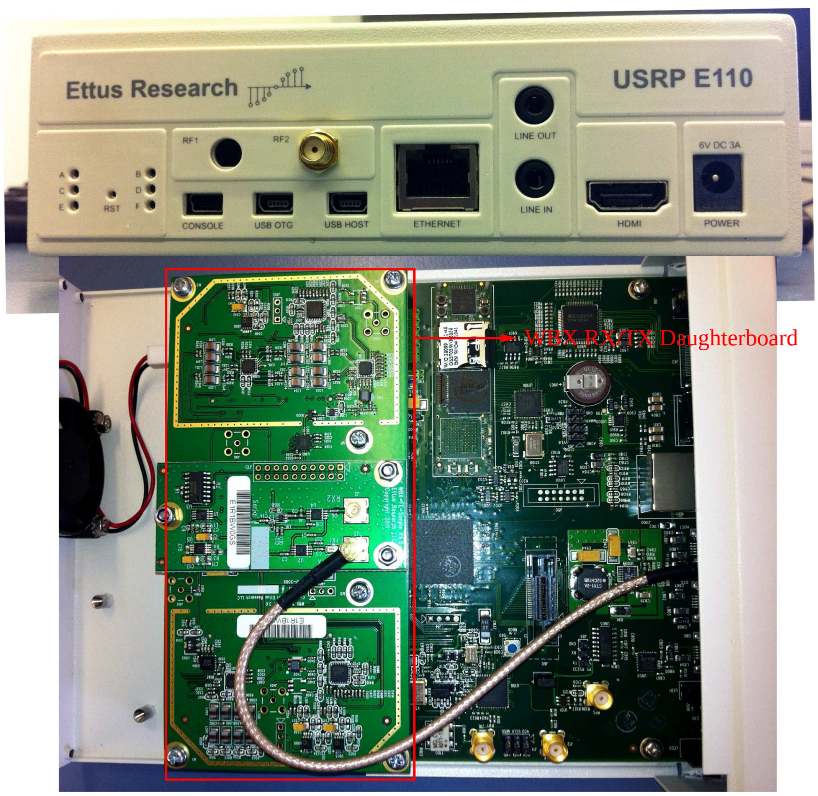

Fig. 1. USRP-E110 external and internal overview. Equipped with WBX Daughterboard.

III. Implementation of an Energy Detection Sensor with USRP-E110

The proposed spectrum sensor gathers power metrics at a determined center frequency f_0 during a fixed *dwelling time* $d_w = 0.001$ s, moving from f_{min} towards f_{max}

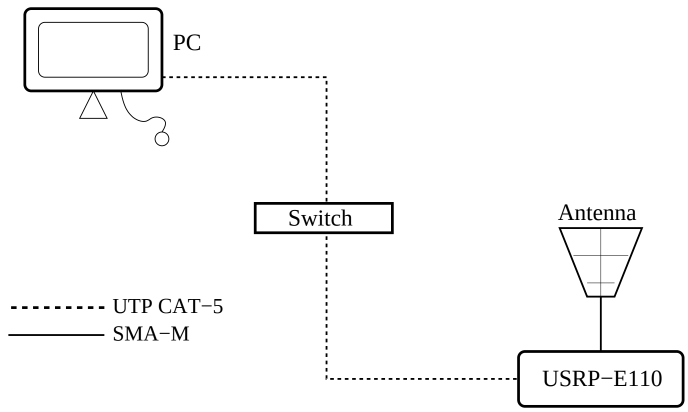

Fig. 2. PC-USRP connections layout

at SS frequency intervals. We denote the signal power at interval i as P_i and $T = (f_{max} - f_{min})/SS$ samples are taken in total. Since SS is typically smaller than the width of a TV channel, several samples are taken for each TV channel.

The procedure described above is conventionally performed using a spectrum analyzer. The resolution bandwidth in the spectrum analyzer is equivalent to our SS. In our prototype, there is not a concept equivalent to the spectrum analyzer's video bandwidth, as we do not apply any further filtering on the P_i values.

A. Identifying TV White Spaces

After all the signal power readings (or collection) are contained in a file, a threshold (γ in (1)) is defined.

$$\gamma = avg(\min P_i, \max P_i) \tag{1}$$

If a received power in the collection (P_i, $i = 1, 2, ..., T$) is greater than γ, then the whole channel at which the sample belongs to is considered *occupied*. On the contrary case, it is considered *free* if $P_i \leq \gamma$. This measure is used in order to avoid channels where narrow-band transmissions might be present (like wireless microphones).

A graphical representation is found in Fig. 3, where $f_{min} = 471.25$ MHz, $f_{max} = 863.25$ MHz and $SS = 250$ kHz, resulting in thirty two power samples per TV channel.

IV. RESULTS

Figure 3 shows the power levels in the collection. Note that the X-axis is labeled with UHF TV channel numbers, each one 8 MHz-wide and able to contain a maximum of four standard resolution or two high definition TV channels.

One of the tasks of the proposed algorithm [8] is to assign a state (free or occupied) to each channel based on its power readings (in this case, thirty two readings per UHF TV channel). Each channel's state can be identified by looking at the right-hand side Y-axis in Figure 3.

A study performed by Domingo *et al.* [9], documented a spectrum sweep with a spectrum analyzer aimed at finding TV White Spaces at the same location as the testings in this work. The presented approach matched nearly 70% of their observations, revealing 29 TV White Spaces against the 35 observed with the spectrum analyzer. This lower number is possibly due to narrow-band transmissions detected by the USRP.

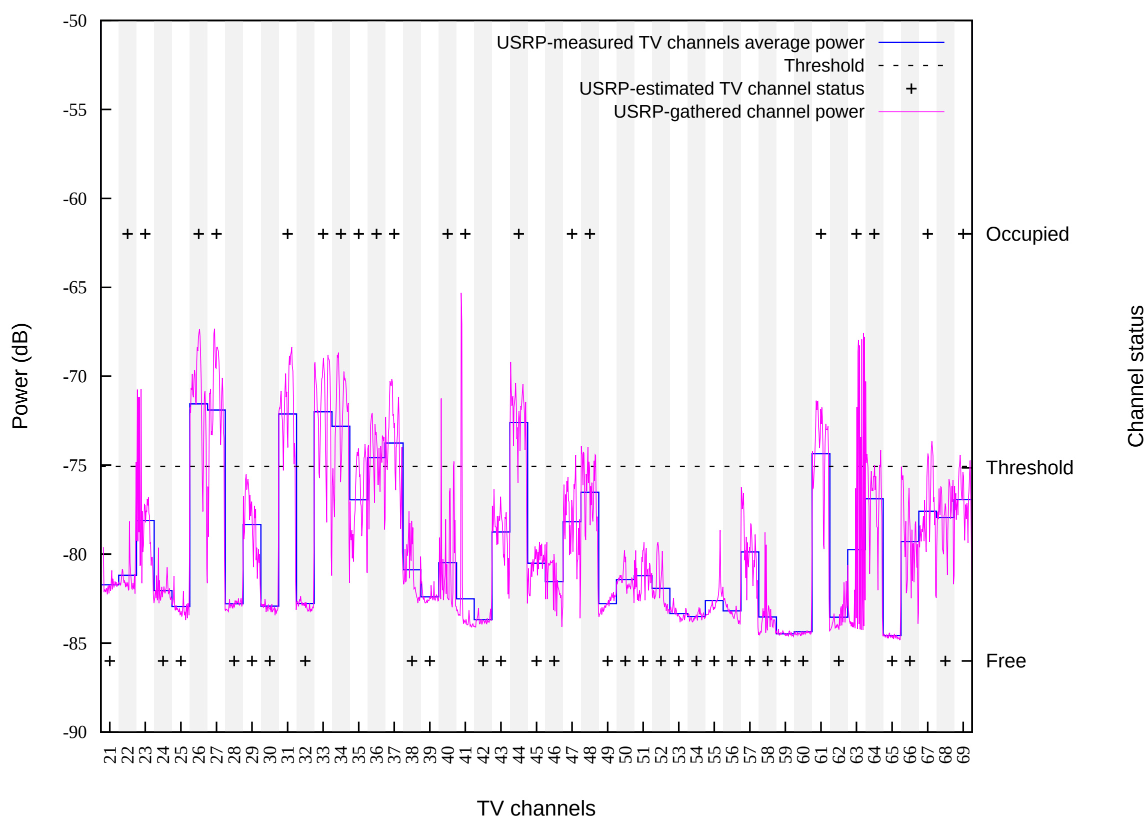

Fig. 3. USRP-estimated TV White Spaces

V. Conclusion

The proposed identification of TV White Spaces with USRP-E110 enables the execution of a spectrum sensing algorithm via SSH, allowing the USRP to be located at convenient locations.

It is possible to build a Radio Environment Maps (REM) [10] from samples gathered by geographically distributed USRPs controlled from a centralized location, increasing the efficiency and boosting the implementation of cognitive networks.

In order optimize the spectrum sensing algorithm, better signal processing techniques are expected to be implemented in the near future [1]. All of this in the attempt to differentiate noise from TV broadcast signals.

Currently, our research is oriented towards the effective communication of two USRP-E110 using TVWS at distances over three meters apart [11]. Also, we are working at combining the cognitive and transmission tasks inside a unified code running in the USRP-E110.

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