Demo: Concurrent Spectrum Sensing for Cognitive Radio using Self-Interference Cancellation

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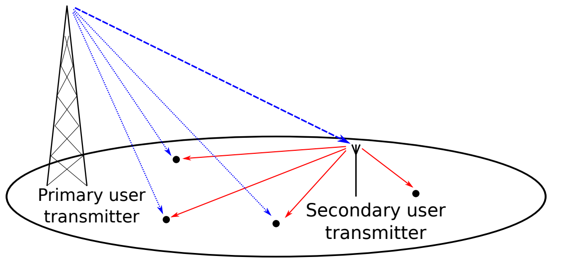
ABSTRACT

A demonstration of a cognitive radio network that supports concurrent spectrum sensing and transmission is presented. Similar to full-duplex transceivers, an analog cancellation signal is used to reduce the self-interference arising from the transmitter to the co-located spectrum sensing circuitry, so that primary users operating in the same frequency band can be detected. The system is implemented on a National Instruments Universal Software Radio Peripheral (USRP) platform and operates at 2.2 GHz. The demonstration will show that continuous spectrum sensing avoids the overhead for dedicated sensing periods and reduces primary user detection latency.

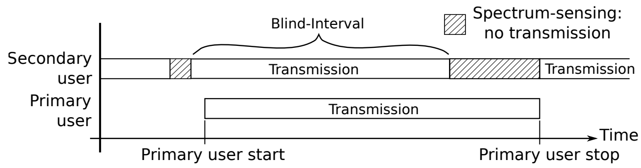
1. INTRODUCTION

Cognitive radio has been proposed to improve spectral efficiency by introducing opportunistic reuse of temporarily under- or un-used frequency spectrum [6]. Fig. 1(a) shows a simplified cognitive radio system, where a secondary user communicates with the receiver nodes when the primary user is not active. Primary users may have priority access rights to some frequency bands (e.g., licensed spectrum). Therefore, secondary users with cognitive radio capability must be able to rapidly detect the presence of these primary users and switch to other unoccupied frequency bands.

Many spectrum sensing algorithms and techniques have been proposed and implemented (for an overview, refer to [6]). Typically, sensing is not performed concurrently with transmission, as the antennas connected to transmit and spectrum-sensing circuits are usually physically close and significant levels of self-interference would 'swamp' the sensing procedure. Accordingly, most approaches rely on periodically stopping secondary user transmissions to sense the channel [6], i.e., to 'listen' for the primary users, as illustrated in Fig. 1(b). There is a trade-off in establishing appropriate sensing periods and duration: shorter intervals between



(a)



(b)

Figure 1: (a) Overview of a cognitive radio system.are not transmitting. For simplicity, only the down-link portion is shown. (b) Primary and secondary user transmissions over time.to 'listen' for primary users.

sensing or longer listening periods reduces the efficiency of the secondary users; however, increasing the interval or reducing the duration potentially increases interference to the primary users. In addition, the 'blind-interval' between sensing periods can increase the latency between the start of primary user transmissions and the stop of the secondary user, which is a concern for 5G systems.

In this demonstration we present the first hardware implementation of a concurrent transmission and spectrum-sensing cognitive radio system. We avoid overloading and 'swamping' the spectrum-sensing circuit by actively suppressing the (known) self-interference transmitted signal using an appropriately generated RF cancellation signal. It has been shown that concurrent spectrum-sensing can improve secondary user throughput [4] and lowers the risk of interference to a primary user [2]. However, these and other similar studies are largely theoretical and neither hardware implementations nor demonstrations have been previously reported.

An important contribution of this demonstration is the

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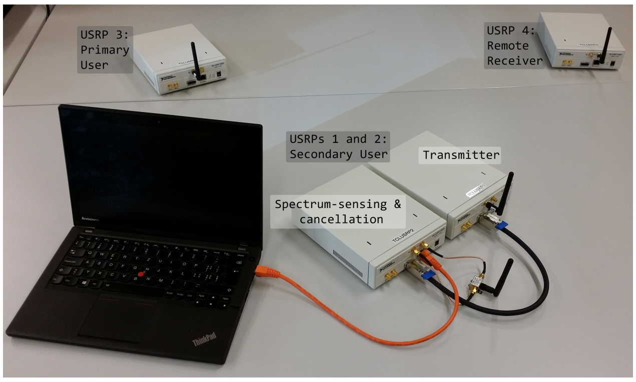

Figure 2: Annotated photograph of the cognitive radio network proposed for demonstration.

evaluation of spectrum-sensing algorithms under realistic conditions, i.e., in the presence of residual self-interference. For example, [4] and [2] use energy-detection algorithms to identify primary user transmissions by assuming near-perfect cancellation of the self-interference (i.e., suppression below the thermal noise-floor). In practise, perfect suppression is usually not attained, due to phase-noise, other hardware impairments, and uncertainty in the channel estimates [5]. For typical operating conditions, the residual self-interference is above the noise-floor, and this can make it difficult to demodulate weak external signals. However, for cognitive-radio, the goal is only to *detect* the presence of a primary user, and not necessarily to correctly decode the transmissions. In this case, reliable spectrum-sensing performance may be achieved at a lower signal-to-noise ratio, again often involving a trade-off with detection latency.

2. OVERVIEW OF DEMONSTRATION

The demonstration is implemented on four National Instruments (NI) 2920 USRP transceivers [1]. The NI USRP-2920 operates at carrier frequencies of 50 MHz to 2.2 GHz and provides output power ranging from -11 dBm to 20 dBm. The demonstration system will use a 2.2 GHz carrier frequency. The USRPs are programmed over Ethernet from a laptop computer, running the Labview software platform, which also performs data processing. If the spectrum-sensing algorithms detect transmission from a primary user, the cognitive radio will quickly switch the transmitter to an unoccupied channel (or off). In the demonstration, the remote receiver will then receive from the primary user. The detection latency of the concurrent approach will be compared to conventional spectrum-sensing, as shown in Fig. 1(b).

2.1 Self-Interference Cancellation

Two of the USRP transceivers (USRPs 3 and 4 in Fig. 2) are assigned the roles of primary user transmitter and remote-user receiver respectively. The two remaining USRPs are used to form the secondary user full-duplex transmit node, as shown in Fig. 2. In the demonstration, the nodes will be separated by approximately 2–3 meters. USRP 1 acts as the transmitter, modulating and sending data into the channel, while spectrum-sensing is performed by the receiver in USRP 2. USRP 2 also sounds and estimates the self-interference channel, and generates an appropriate RF cancellation signal. The cancellation signal is then ‘subtracted’ from the incoming signal via an external combiner, reducing the power of the self-interference so that transmissions from the primary user may be detected. It should be noted that entirely-digital cancellation is not feasible in practise due to the limited resolution of the analog-to-digital converters when the received primary user signal is small relative to the self-interference [5]. The self-interference signal is also attenuated when propagating between the transmitting and spectrum-sensing antennas.

A 10 MHz reference clock is shared between transmit and cancellation USRPs. The carrier is regenerated within each USRP from this reference signal. In this configuration, each local oscillator has independent phase-noise, which tends to limit the self-interference cancellation that can be achieved [3]. Therefore, primary-user detection algorithms that perform well in the presence of noise and interference are required. In this demonstration we use energy- and waveform-detection algorithms to sense the channel under realistic noise and self-interference conditions. Our cognitive radio system implementation can detect the presence of the primary user (and respond appropriately by turning off the secondary user) within 20 ms from the start of transmission.

2.2 Requirements

To successfully demonstrate our concurrent cognitive radio system at MOBIHOC’15 we will require:

- A 2×2 m table to position the USPRs and laptops;
- Power and internet connections; and
- Space and a supporting board to hang a poster.

The required set up time is approximately 30 minutes. All other required equipment for the demonstration will be brought by the authors.

3. REFERENCES

[1] NI USRP-292x/293x Datasheet. http://www.ni.com/datasheet/pdf/en/ds-355.

[2] W. Afifi and M. Krunz. Adaptive transmission-reception-sensing strategy for cognitive radios with full-duplex capabilities. In *Proc. IEEE Intl. Symp. Dynamic Spectrum Access Networks (DYSPAN)*, pages 149–160, 2014.

[3] A. Balatsoukas-Stimming, P. Belanovic, K. Alexandris, and A. Burg. On self-interference suppression methods for low-complexity full-duplex MIMO. In *Proc. Asilomar Conference on Signals, Systems and Computers*, pages 992–997, 2013.

[4] T. Riihonen and R. Wichman. Energy detection in full-duplex cognitive radios under residual self-interference. In *Proc. Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM)*, pages 57–60, 2014.

[5] A. Sabharwal, P. Schniter, D. Guo, D. Bliss, S. Rangarajan, and R. Wichman. In-band full-duplex wireless: Challenges and opportunities. *IEEE J. Sel. Areas Commun.*, 32(9):1637–1652, 2014.

[6] T. Yücek and H. Arslan. A survey of spectrum sensing algorithms for cognitive radio applications. *IEEE Commun. Surveys Tuts.*, 11(1):116–130, 2009.