Energy Detection in Full Duplex CRNs using Estimator Correlator with PU Signal Uncertainty

Abhishek Kumar, Tripta, and Seemanti Saha*
National Institute of Technology Patna, Patna, India-800005

This paper presents a novel energy detection based spectrum sensing technique for full duplex (FD) cognitive radio networks (CRNs) under residual self-interference (RSI) considering primary user (PU) signal with arbitrary covariance matrix that affirms a more realistic scenario in heterogeneous networks for future wireless applications. In in-band FD mode, secondary users (SUs) can sense and transmit simultaneously using the same channel, doubling the spectrum efficiency of the FD enabled CRNs (W. Afifi and M. Krunz, IEEE Trans. Wireless Commun., 4, 2180-2191, 4015). Researchers have extensively worked on spectrum sensing in CRNs under noise uncertainties (S. Gong, et al., IEEE Proceeding ICC, 1512-1516, 6012), but signal uncertainty is another limiting factor that results in additional detection performance degradation (M. Lopez-benitez and F. Casadevall, IEEE Trans. Commun., 4, 1231-1241, 2013). In this work, we address this issue considering PU signal having uncertain/arbitrary covariance structure that supports various radio technologies and standards. The proposed energy detector (ED) correlates the received signal sample with an estimate of the transmitted signal sample obtained by Wiener estimator and provides a log likelihood ratio test (LRT) based detection of the PU signal. The block schematic diagram of the proposed ED is shown in Fig. 1, in which LRT statistic could be formed as:

$$T(y) = \mathbf{y}^T \left[\frac{1}{\sigma^2_{H_0}\mathbf{I}} \left(\frac{1}{\sigma^2_{H_0}\mathbf{I}} + \mathbf{C}_x^{-1} \right)^{-1} \right] \mathbf{y} \;=\; \hat{\mathbf{x}}\mathbf{y} \geq \gamma, \tag{1}$$

where, $\hat{\mathbf{x}} = C_x(C_x + \sigma^2_{H_0} I)^{-1}\mathbf{y}$ is an Wiener filter estimate of the PU signal, C_x is an arbitrary co-variance structure of PU signal, N is the total number of samples used for sensing in a particular sensing period, $\sigma^2_{H_0}$ is the variance of the received signal under hypothesis H_0 which represents the absence of PU signal, and γ is the threshold value determined by the fixed false alarm probability (P_{fa}) and is obtained as $\gamma = \sigma^2_{H_0}\left\{Q^{-1}(P_{fa}/2)\right\}^2$.

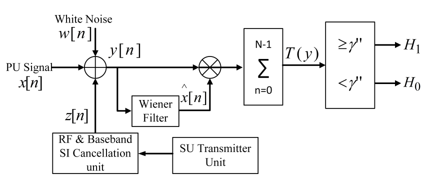

Figure 1: Block schematic of proposed ED

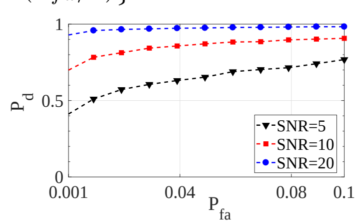

Figure 2: Roc plot (AWGN)

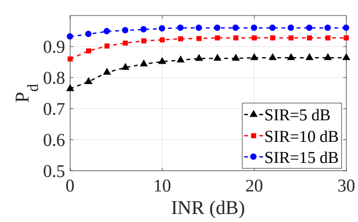

Figure 3: $P_d$vs.INR (AWGN; N=10)

The performance evaluation of the proposed algorithm in AWGN channel through MATLAB simulation is depicted in Fig. 2−3, which show probability of detection (P_d) performance under RSI in FD-CRN. The parameters considered are signal-to-noise ratio (SNR), signal-to-interference ratio (SIR), interference-to-noise ratio (INR) and N, where $SNR(dB) = SIR(dB) + INR(dB)$. The ROC plot, depicted in Fig. 2 clearly shows that P_d increases with increase in SNR. P_d vs. INR plot for different values of SIR at $N = 10$ is conferred in Fig. 3 that shows degradation in detection performance with decrease in SIR, which affirms the adverse effect of RSI on detection. Finally, it is inferred that, target detection probability ($P_d \geq 0.9$) could be achieved with $N = 10$ and $SNR = 10dB$, validating the applicability of the proposed sensing algorithm in FD CRNs. The detection performance can be further improved by employing efficient SI cancellation techniques and the work could be further extended in MIMO FD CRNs in future.