Demonstration of Real-time Spectrum Sensing for Cognitive Radio

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Outline

• Background and Introduction

• Proposed Algorithm for Spectrum Sensing

• Implementation of the Proposed Algorithm on Hardware Platform

• Performance Evaluation

• Demonstration of Real-time Spectrum Sensing

• Conclusion
Cognitive Radio

- Cognitive Radio – a technique of utilizing unused spectrums to communicate efficiently for secondary (unlicensed) users without interfering primary (licensed) users.
- Spectrum sensing – a cornerstone function of cognitive radio, for detecting unused spectrum without interfering primary users, which is usually performed periodically.
Challenges for Spectrum Sensing Algorithm

- A good spectrum sensing algorithm should offer high probability of detection ($P_D$) at low probability of false alarm ($P_{FA}$) for a wide range of signal-to-noise ratio (SNR).

- From a practical perspective, a good spectrum sensing algorithm has to be implementation friendly, including acceptable computational complexity.
Popular Off-the-Shelf Hardware Platforms for Cognitive Radio

- Small form factor (SFF) software defined radio (SDR) development platform (DP)

- The next generation universal software radio peripheral (USRP2)

For more information about the two platforms, please refer to:
Major Contributions of This Paper

• The platform employed in our research is real-time oriented compared to some of those reported.

• An FFT-based spectrum sensing algorithm (FAR), which is more implementation-friendly, is proposed in this paper. The decision threshold of FAR is insensitive to noise level.

• The relationships between the length of FFT, the length of averaging and the SNR are experimentally investigated.

• Both $P_D$ and $P_{FA}$ of the spectrum sensing algorithm are measured on hardware platform.

• A real-time spectrum sensing is demonstrated with controllable primary users (PUs).
The Proposed FAR Algorithm

- **Input**: baseband discrete-time signal
- **Output**: a series of vectors of two-class decisions that represent the availabilities of the channels in each time slot

\[
\begin{align*}
    r(k) &= \frac{P_{\text{avg}}(k)}{P_m} \\
    P_{\text{avg}}(k) &= \frac{1}{T} \sum_{t=0}^{T-1} P_t(k) \\
    P_m &= \frac{2}{N + 2} \sum_{k=0}^{N/2} P_{\text{avg}}(k) \\
    P_t(k) &= |X_t(k)|^2 \\
    k &= 0, 1, \ldots, \frac{N}{2} \\
    t &= 0, 1, \ldots, T - 1
\end{align*}
\]
• The ratio $r(k)$ is independent of noise level!
• The threshold of FAR algorithm

The pure-noise PDF does not change with noise level and SNR!
Discussions (2/2)

- **Length of FFT and length of averaging**

Both of the required lengths increase approximately exponentially as SNR goes down.

Both the local minima of the required number of complex multiplications and the local minima of the required number of samples are achieved at $(N, T) = (512, 9)$, $(1024, 4)$, $(1536, 2)$ and $(2048, 2)$. 
• Small form factor software defined radio development platform (SFF SDR DP)

FAR algorithm (N = 128, T = 16)

RF module | Data conversion module | Digital processing module

RF | ADC | FPGA1 | FPGA2 | DSP

Signal analyzer

Arbitrary waveform generator

Family radio service (FRS)

Digital phosphor oscilloscope
• Setup for performance evaluation

Recorded FRS signals
The implemented FAR algorithm works well when the received maximum PSD is -121 dBm/kHz or above. With $P_{\text{FA}}$ close to zero, the FAR algorithm on the SFF SDR DP can achieve a high $P_D$ when the maximum PSD is -121 dBm/kHz or above, noting that typical PSD of the received FRS signal is higher than our detection limit.
Real-time Demonstration (1/2)

Layoff for real-time demonstration

Setup for real-time demonstration
The sensed channel states match the recorded channel waveforms very well.
Conclusion

• FAR algorithm for spectrum sensing has been proposed.
  – FAR algorithm is designed to compromise between the performance and implementation complexity.
  – FAR algorithm has a constant threshold feature which is greatly in favor of blind sensing.

• Selection for major parameters of FAR algorithm has been discussed.

• Spectrum sensing receiver with FAR algorithm has been implemented on the SFF SDR DP and tested using real FRS signals.
  – Performance evaluation shows that FAR algorithm is indeed effective.

• Real-time spectrum sensing with controllable PUs has been demonstrated.
Thank you!