Channel-Adaptive Sensing Strategy for Cognitive Radio Ad Hoc Networks

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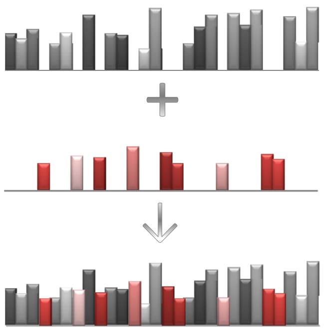
Introduction



- ❑ Cognitive Radio (CR) allows SUs share the spectrum with PUs to improve spectrum utilization.
- ❑ The PU activities should not be severely interrupted.

Observation

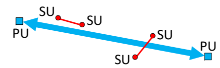
- ❑ SUs can sense a limited portion of the spectrum each time.
- ❑ Neighboring SUs experience similar spectrum opportunities
- ❑ To maintain high throughput, SUs should:
  - ➢ Sense/access the channels that are not used heavily by PUs.
  - ➢ seek spectrum opportunities on different channels to avoid SU collisions.
- ❑ In a wireless environment, the powers of SU-to-SU and PU-to-SU links vary over space and frequencies.
- ❑ Adapting the reward to the channel state information (CSI) can improve the individual throughput.
- ❑ With different SU sensing preferences, competition among SUs can be readily resolved.

CSI-Aided Sensing

- ❑ In the proposed CSI-aided sensing policy, the reward is given by the channel capacity:

$$R_{cap}^{mn}(t) = C^{mn}(t) = B_n \log_2(1+\gamma^{mn}(t)),$$

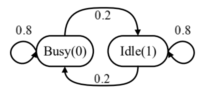
where B_n is the bandwidth of the n^{th} channel and $\gamma^{mn}(t)$ is the received SNR of the n^{th} channel for the m^{th} SU pair.



- ❑ This reward is a function of the instantaneous CSI and varies over SU locations and over channels, randomizing the sensing decisions and improving the individual throughput.

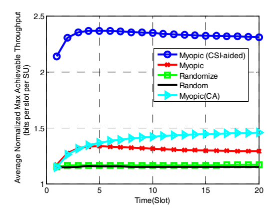
Simulation Results

- ❑ 20 SU pairs and 40 channels with the same bandwidth B=1 (unless noted otherwise).



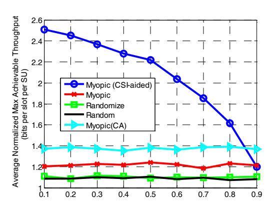
- ❑ The PU traffic on each channel evolves independently according to a Markov chain with the transition probabilities shown above.

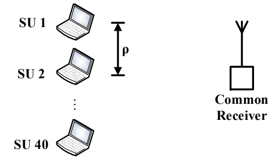
A. Ideal CSI



- ➢ i.i.d. Rayleigh fading, avg SNR=10dB.
- ➢ All policies employ channel capacity as the accumulated reward.
- ➢ The gain of the CSI-aided policy is at least 0.8 bits/slot /SU.
- ➢ This gain is due to channel adaptation prior to sensing.

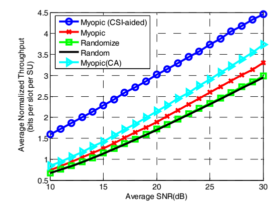
B. Robustness to Spatial Correlation





- ➢ Adapting to shadow fading is more practical.
- ➢ Shadow fading is correlated in space and frequency, reducing multiuser diversity gain.
- ➢ Lognormal shadow fading, avg SNR=10dB, dB spread=5dB.
- ➢ Throughput degrades as the correlation (ρ) increases.
- ➢ In ad hoc networks, ρ is below 0.3, so multiuser diversity gain is mostly preserved.

C. Adaptive Modulation

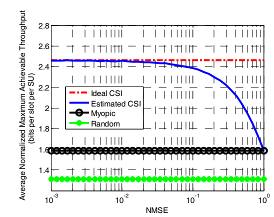


- ➢ Assume QAM adaptation with fixed tx power:

$$R_{AM}^{mn}(t) = B_n k^{mn}(t),$$

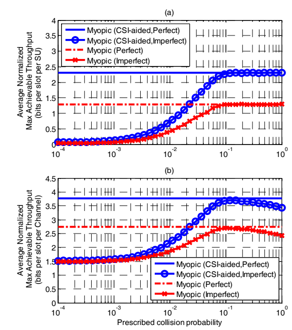
where $k^{mn}(t)$ is the max spectral efficiency that the system can support under a certain BER constraint (10^{-3}).
- ➢ CSI-aided policy outperforms all others by at least 5 dB in realistic SNR range.

D. Robustness to CSI Mismatch



- ➢ Channel gain is required prior to sensing – employ pilots.
- ➢ 3 SU pairs, 10 channels.
- ➢ CSI mismatch: $R(\hat{\gamma}) = \int_0^{\infty} R(\gamma) f(\gamma \mid \hat{\gamma}) d\gamma$.
- ➢ Approximates the ideal CSI case when NMSE <0.1.
- ➢ Degrades gracefully to the conventional myopic policy as NMSE increases.

E. Performance under Sensing Error



- ➢ Energy detection.
- ➢ i.i.d Rayleigh fading, avg SNR=10dB.
- ➢ The SU network throughput approaches the ideal case, but PU throughput is reduced as maximum allowed collision probability (p_m) grows.
- ➢ The optimal value of p_m is 0.1.
- ➢ Maintains 1 bit gain over the conventional myopic policy for $p_m \geq 0.1$.

Conclusion

- ❑ We proposed to adapt the reward to the SU link CSI in the CR ad hoc network sensing strategy design.
- ❑ This method improves the SU throughput and provides multi-user diversity by randomizing sensing decisions.
- ❑ CSI-aided strategy achieves a throughput gain of about 1 bit/slot/SU or at least 5 dB over other sensing strategies.