Multi-Antenna Interference Cancellation Techniques for Cognitive Radio Applications

Omar Bakr
Ben Wild
Mark Johnson
Raghuraman Mudumbai (UCSB)
Kannan Ramchandran
Last Time

- Improving spectrum reuse using primary and secondary collaboration\(^1\)
- More effective spatial reuse using multiple antennas on the secondary
- Example: cellular uplink reuse
- Today: signal processing and array processing techniques to improve collaboration
- To appear in IEEE WCNC 2009

Cellular uplink reuse framework

- Cellular downlink
- Cellular uplink
- Secondary network on Cellular uplink

Cellular Base Station

Secondary User

TX

Secondary User

RX

Cell phones

Beam Null

Interference (from primary to secondary)
Collaborative framework for interference cancellation

- $h_j$ for $0 < j < K+1$ are the channel responses from the secondary transmitter ($\text{SR}_t$) to each of $K$ primary users (base stations) respectively.
- $h_d$ is the channel response from $\text{SR}_t$ to $\text{SR}_r$.
- Choose $c$ to be the component of $h_d$ that is orthogonal to $h_j$ for $0 < j < K+1$ (projection).
- Channels unknown apriori? Need to estimate.
Estimation using adaptive filtering

- Identifying an unknown filter (channel) $H(z)$ using an adaptive filter (e.g. Least Mean Square (LMS) algorithm)
- $w[n]$ is a known pseudo random sequence, $G_n(z)$ is the local estimate
- $G_n(z)$ will converge to a noisy estimate of $H(z)$ (due to the presence of noise)
- In the beamforming context, the taps of $H(z)$ are the complex responses from each antenna element on the secondary radio towards a primary radio
Beam-nulling using adaptive filtering

feedback on cellular downlink $y[n] = \sum h_i w_i[n] + \nu[n]$

Secondary Radio Transmitter Running Adaptive LMS Algorithm
Simulated interference rejection

-22 dB attenuation

4 primary users (base stations), cognitive radio has M antennas

Infinite phase/amplitude resolution

Finite phase/amplitude resolution
Iterative channel estimation

- Less coordination among primary users
- Better reuse of allocated channels
- Same adaptive algorithm, different choice of training sequence $w$
- Adaptively perform a Gram-Schmidt orthogonalization
  - Start with the closest node (e.g. PR1)
  - Run LMS at low power (no interference to other nodes)
  - After estimating $h_1$, increase the power and choose $w$ orthogonal to $h_1$
  - This will estimate the component of $h_2$ orthogonal to $h_1$
  - Increase the power, choose $w$ orthogonal to both $h_1, h_2$
Simulated interference rejection

Infinite phase/amplitude resolution

Finite phase/amplitude resolution

4 primary users (base stations), cognitive radio has 12 antennas

~22dB attenuation
What about the receiver
Interference suppression framework

- Primary transmitters (cell phones) can cause interference to the secondary (cognitive radio) network

- At the secondary receiver:
  - \( y[n] = h_d d[n] + \sum_i h_i d_i[n] + v[n] \)

- Choose beamforming (spatial filter) to maximize SINR
  - \( \text{SINR}_{\text{out}} = \frac{|c^h h_d|^2}{\left( \sum_i |c^h h_i|^2 + N_v \right)} \)

- MMSE criterion:
  - \( c_{\text{MMSE}} = \arg \min_c |e[n]|^2 = \arg \min_c |c^h y[n] - d[n]|^2 \)

- Good rejection in slow fading channels

- Doppler/frequency offsets can create problems
Differential MMSE Framework

- Even in fast fading environments, channel remains relatively constant over successive symbols
- Avoid tracking channel variations by only looking at the difference (ratio) between symbols (similar to differential modulation)
- DMMSE criterion:
  - \( c_{DMMSE} = \arg \min_c |c^h y[n-1]d[n] - c^h y[n]d[n-1]|^2 \)
  - Subject to \( E[|c^h y[n]|^2]=1 \)

Simulated interference rejection

8 antennas, 6 interferers, $\text{SNR}_{\text{in}}=-20\,\text{dB}$, $\text{SIR}_{\text{in}}=-40\,\text{dB}$

DMMSE, offset=10% symbol rate

NLMS, offset=1% symbol rate