Combining Cognitive Radio and Software Radio Approach for Low Complexity Receiver Architecture

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Overview

• Motivation

• Cognitive Radio Enhancement

• Software Radio Complexity

• Conclusion
Motivation
Requirement when combining Cognitive and Software Radio

• Cognitive Radio for spectrum efficiency
  • analyzing user application
  • definition of wireless requirements
  • spectrum scanning
  • definition of radio characteristics

• Software Radio
  • adjusts transmitter and receiver algorithms
  • transforms algorithms to an applicable architecture
  • maps the architecture on available processor platform
  • balances between different, parallel operating radios

• To achieve efficient receiver implementations Software Radio requires
  • strong flexibility in terms of
    • algorithm complexity
    • power consumption
  • support from Cognitive Radio
Processor load as measure for algorithms complexity

Receiver algorithms utilizing the processor

- Freq. Sync
- Decoding
- Channel Estimation
- Timing Sync
Cognitive Radio Enhancement
Channel-State Estimation

- Channel-State Estimate to judge about channel capacity

- Semi-blind training
  - Supervised training mode via short training sequence
  - Tracking via data feedback

- Rate feedback to transmitter to setup
  - data rate
  - transmit-power control
Transmit Power Control

• Power initialization

• Inner Loop
  • Allocation of a number of channels

• Outer Loop investigates achieved data rate
  • exceeding
  • matching
  • undershooting

• Outer Loop adjusts the transmit power of each transmitter
  • All transmitters run from data-rate perspective with optimal transmit power
  • *What is about the receiver complexity?*
Cognitive Radio Enhancement

- Each receiver includes an option to ask for low receiver complexity
  - Transmit-power increase
  - High quality channel selection

- Transmit-power increase
  - Other transmitters reduce power
  - Other receivers increase complexity

- High quality channel selection
  - Find a better fitting free channel
  - Exchange already allocated channels
Software Radio Complexity
Receiver Algorithms with different Complexities

- Different receiver complexities based on channel-state estimation
- Receiver complexities can change at any time

Diagram:

- Channel State Estimation
  - Nearly ideal channel:
    - simple filters -> short FIRs
    - Channel estimation -> Least Squares
    - Simple channel decoder -> direct decision
  - Time variant channel:
    - improve filters -> longer FIRs
    - Channel estimation -> Least Squares + Linear interpolation
    - Channel decoder -> few, parallel RNNs with very few iterations
  - Strong interference, fast time varying channel:
    - steep filters -> long FIRs
    - Channel estimation -> Wiener
    - Channel decoder -> Viterbi
    - Increase number of receive antennas -> SIMO
Receiver Scaling through Multi-Processor Platforms

• Pure hardware-optimized design can be replaced by multi-processor platform
• Several radios and their algorithms run in parallel

*For parallel programming a significant change of mathematics for radio algorithms might be required*
Example of Parallel Radio Algorithms – Channel Decoding

• Viterbi
  • high signal processing performance
  • optimal for hardware implementation
  • sub-optimal for software radio approach
  • difficult to parallelize

• Recurrent Neural Networks
  • do not outperform Viterbi signal processing performance
  • similar mathematics as adaptive filters
  • easy to parallelize several networks

\[
\min_{w(n)} \|e(n)\|_2^2 = \min_{w(n)} \|X(n)w(n) - \tilde{y}(n)\|_2^2
\]

Adaptive Filter

\[
\min_{a} \|e\|_2^2 = \min_{a} \|r - c\|_2^2 = \min_{a} \|r - G^T a\|_2^2
\]

Recurrent Neural Network
N Parallel Channel Decoders

- Run several networks in parallel
- The more networks, the higher the channel decoding performance
- Research topic – optimize complexity of each channel decoder network
Simulation Results

- Number of RNN networks can be adjusted to channel quality
Conclusion

• Software Radio needs to handle several radios in parallel

• Cognitive Radio should support receiver complexity reduction

• Parallel processor platform should be able to replace optimized hardware

• Mathematics for radio algorithms might change to enable parallel programming