Dynamic Behavior and Coexistence of Intelligent Radio Spectrum Access Systems

PI: Xiaohua Li, Dept of ECE, State University of New York at Binghamton

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Motivation

Complex coexistence behavior of dynamic spectrum access (DSA) systems with different users and spectrum access strategies

General Objective

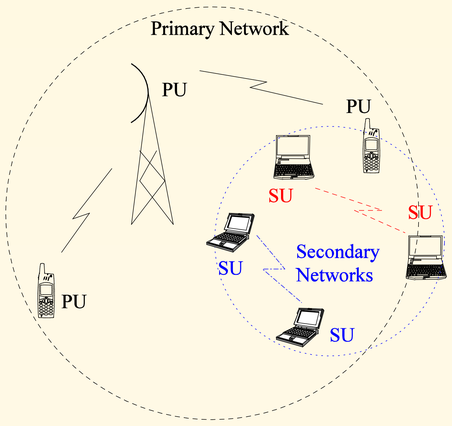
Develop theoretical frameworks for modeling and analyzing the dynamic behavior and coexistence of heterogeneous DSA systems

Research Tasks

- Motivated by theoretical ecology, develop game theoretic and population dynamic models to analyze the interaction of different spectrum access strategies
- Study the performance of wireless spectrum sharing from physical-layer to upper layer
- Develop cognitive radio testbed to support both research and education

Major Achievements

1. Markov model bank (MMB), network decomposition, and polynomial rooting techniques for deriving closed-form results
2. Interference-immune multi-hop relaying, resolve the challenge of mutual interference and inefficient channel access
3. General scheme for most distributed transmission techniques, asynchronously, no need of accurate synchronization



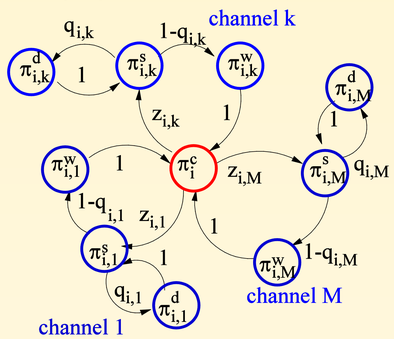
System Level: Competitive Coexistence of Secondary Users

Problem

Develop efficient techniques to model and analyze the cooperation & competition of secondary users

Techniques

- Markov model bank (MMB): a Markov model for each user, interacting via interference
- Network decomposition for complexity reduction, exploiting spatial-, channel- and user- decorrelations
- Closed-form throughput expressions, related to special polynomial roots

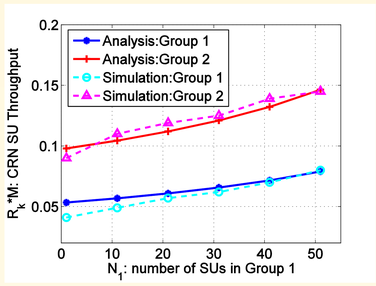


Representative Results

Two groups of secondary users competing for spectrum access. Throughput is derived as

$R_{2k} = b_2 x_{2k} y$, where $y \in [0,1]$ is the root of the polynomial

$$cb_1x_{1k}a_{1k}a_{2k}^{\frac{N_1-1}{N_1}} y^{\frac{N_1-1}{N_1}}(1-cb_2x_{2k}y)^{\frac{N-1}{N_1}} + a_{2k}^{\frac{1}{N_1}} y^{\frac{1}{N_1}}(1-cb_2x_{2k}y)^{\frac{N_2-1}{N_1}} - 1 = 0$$



Major Observations

- Different spectrum access strategies gain different throughputs in competition
- Differently from bio-ecology, randomization greatly helps spectrum-access fairness

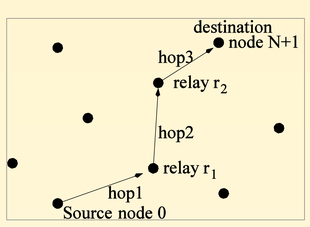
Multi-hop Level: Interference Immune Multi-hop Relaying

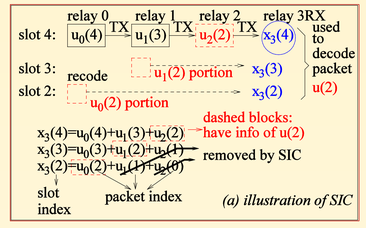
Problem

Multi-hop relaying suffers from mutual interference and inefficient spectrum sharing among relays

Techniques

- Exploit mutual interference rather than cancelling only, new channel access strategy
- Joint re-encoding and success interference cancellation



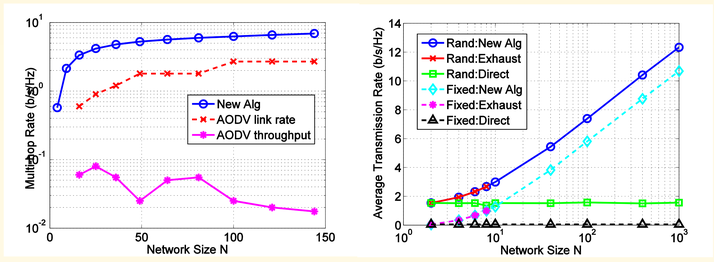


Representative Results

- Optimal throughput (as if no mutual interference)

$$R_{r_j} = \sum_{i=0}^{j-1} \log_2\left[1+\gamma_j(k-j+1+i)\right] = \log_2\left(1+\frac{\sum_{i=0}^{j-1} P_{r_i} G_{r_i,r_j}}{\sigma_j^2}\right)$$

- Wireless Dijkstra's algorithm: find optimal multi-hop path efficiently in arbitrarily large wireless networks
- Resolve a major limitation of multi-hop relaying: time-sharing of channel by relays



Future Directions

Mitigate mutual interference among different paths, or different networks such as 5G and WiFi.

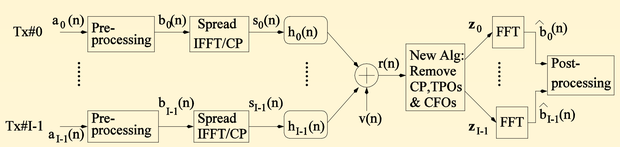
Node Level: Asynchronous Distributed Transmissions

Problem

A general trend of wireless communications is distributed transmission, e.g., relaying, CoMP. A major challenge is carrier/time synchronization.

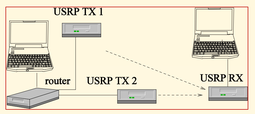
Techniques

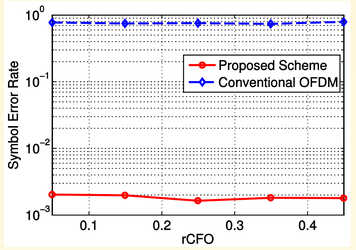
- General scheme that transparently support most distributed transmissions, no need of accurate synchronization in carrier & timing
- OFDM signaling, testbed implementation



Representative Results

- Tolerate extremely large carrier offsets
- Transparent to each specific transmission
- Tested many distributed transmissions





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